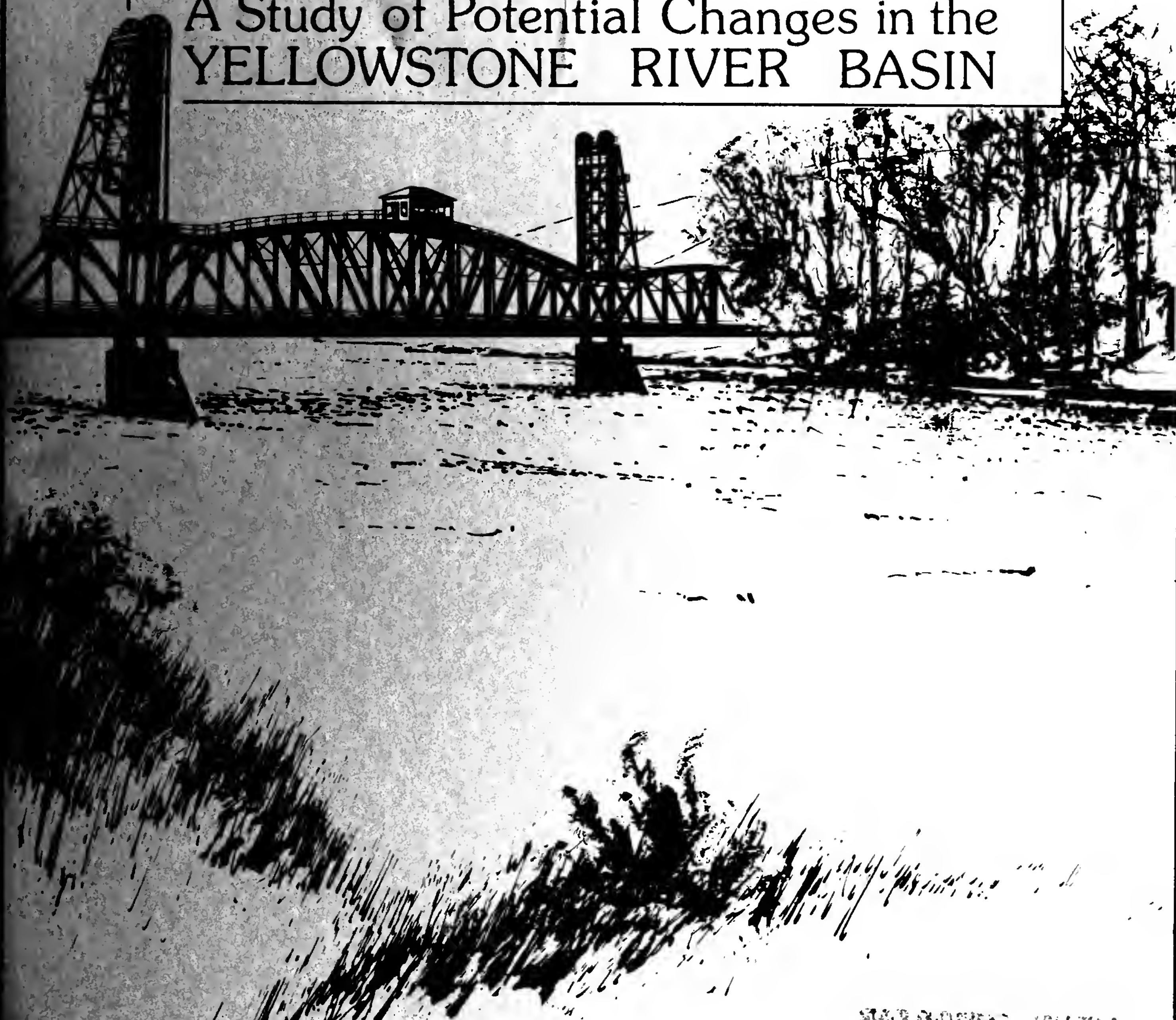
HOW THE RIVER RUNS

A Study of Potential Changes in the YELLOWSTONE RIVER BASIN



DNRC

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION

THE YELLOWSTONE IMPACT STUDY TECHNICAL REPORT SERIES

This report summarizes the **Yellowstone Impact Study**, funded by the Old West Regional Commission and conducted by the Department of Natural Resources and Conservation. These technical reports present the study's results in detail:

Report No. 1	Future Development Projections and Hydrologic Modeling in the Yellowstone River Basin, Montana.
Report No. 2	The Effect of Altered Streamflow on the Hydrology and Geomorphology of the Yellowstone River Basin, Montana.
Report No. 3	The Effect of Altered Streamflow on the Water Quality of the Yellowstone River Basin, Montana.
Report No. 4	The Adequacy of Montana's Regulatory Framework for Water Quality Control.
Report No. 5	Aquatic Invertebrates of the Yellowstone River Basin, Montana.
Report No. 6	The Effect of Altered Streamflow on Furbearing Mammals of the Yellowstone River Basin, Montana.
Report No. 7	The Effect of Altered Streamflow on Migratory Birds of the Yellowstone River Basin, Montana.
Report No. 8	The Effect of Altered Streamflow on Fish of the Yellowstone and Tongue Rivers, Montana.
Report No. 9	The Effect of Altered Streamflow on Existing Municipal and Agricultural Users of the Yellowstone River Basin, Montana.
Report No. 10	The Effect of Altered Streamflow on Water-Based Recreation in the Yellowstone River Basin, Montana.
Report No. 11	The Economics of Altered Streamflow in the Yellowstone River Basin, Montana.

HOW THE RIVER RUNS

A Study of Potential Changes in the
YELLOWSTONE RIVER BASIN

YELLOWSTONE IMPACT STUDY

FINAL REPORT

conducted by the
Water Resources Division
Montana Department of Natural Resources
and Conservation
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Helena, MT 59620

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for the

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February 1981

The Old West Regional Commission is a Federal-State partnership designed to solve regional economic problems and stimulate orderly economic growth in the states of Montana, Nebraska, North Dakota, South Dakota and Wyoming. Established in 1972 under the Public Works and Economic Development Act of 1965, it is one of seven identical commissions throughout the country engaged in formulating and carrying out coordinated action plans for regional economic development.

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FOREWORD

The Old West Regional Commission wishes to express its appreciation for this report to the Montana Department of Natural Resources and Conservation, and more specifically to those Department staff members who participated directly in the project and in preparation of various reports, to Dr. Kenneth A. Blackburn of the Commission staff who coordinated the project, and to the subcontractors who also participated. The Yellowstone Impact Study was one of the first major projects funded by the Commission that was directed at investigating the potential environmental impacts relating to energy development. The Commission is pleased to have been a part of this important research.

George D. McCarthy
Federal Cochairman

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INTRODUCTION

In the fall of 1974, the Montana Department of Natural Resources and Conservation began a study designed to evaluate the potential effects of water withdrawals and water development on Montana's portion of the coal-rich, highly agricultural Yellowstone River Basin. Entitled the Yellowstone Impact Study, the investigation was funded by the Old West Regional Commission and involved a number of Montana government agencies. Among the tasks undertaken were these:

1. assessment of the effects of coal development on water quality in the basin;
2. investigation of the effects of altered streamflow on water-based recreation;
3. assessment of the effects of altered streamflow on the basin's migratory birds and furbearing mammals;
4. use of a computerized model to simulate the streamflow characteristics of the basin; and
5. assessment of the effects of altered streamflow on irrigated agriculture and on municipal water supplies.

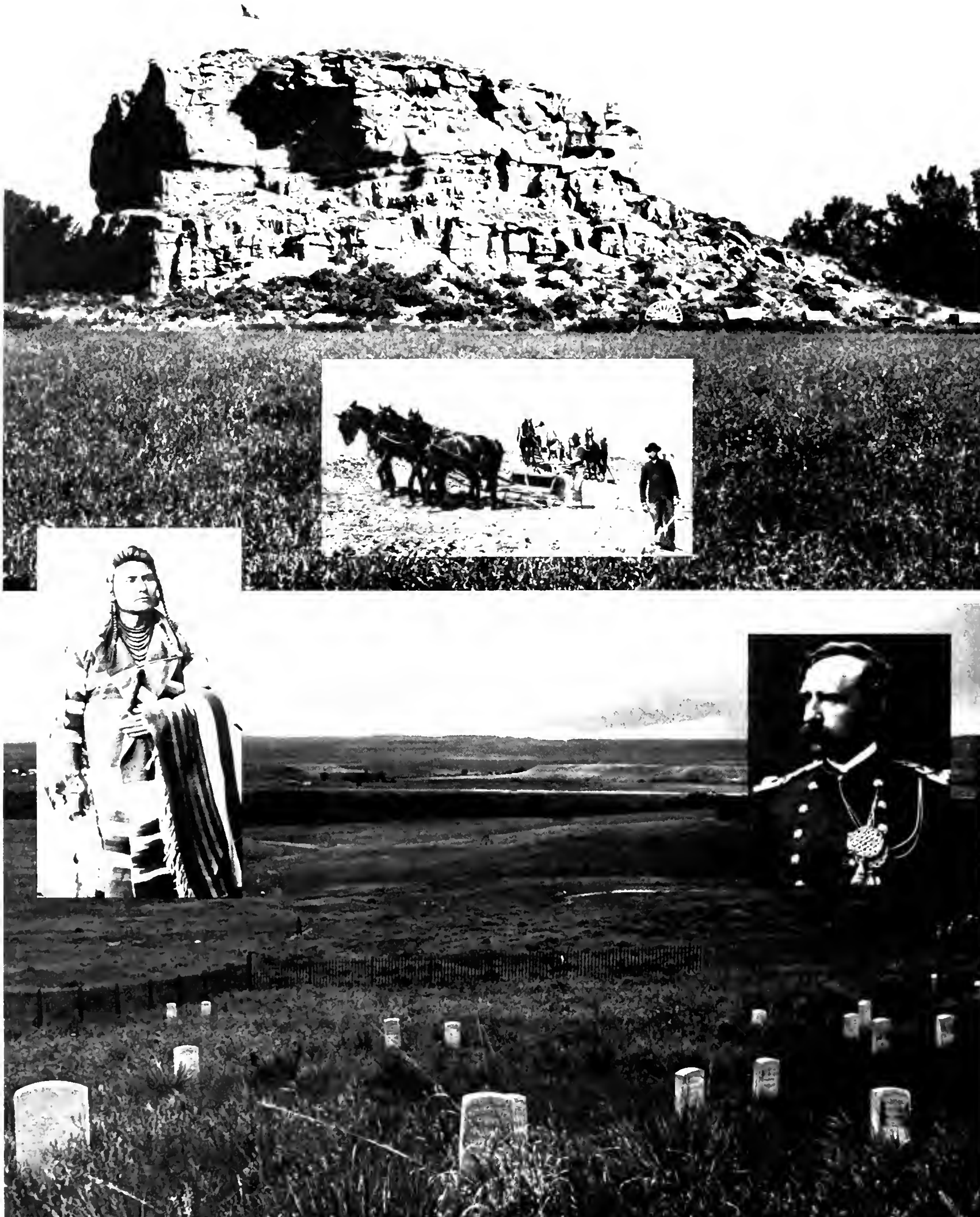
There were a number of other tasks. All were complex. Migratory birds, for example, would be most affected not by the mere lowering of the water's surface but by permanent changes in the river's channel—loss of islands and bars, say, or the growth of trees and bushes on previously bare banks. How do you determine the likelihood of any such changes without knowing how much water may be taken out of the river for future energy and irrigation development, and whether dams may be built on the river? How do you project how much water energy development might use without knowing how much coal there is, and what it will be used for, and where? And how do you decide whether dams will be needed without knowing how much water is still available for appropriation in the basin and from what streams, and at what times of year? Each answer raised more questions. But with a river at stake, and with it much of our state's future, the answers were worth finding. The Yellowstone Impact Study found many of them.

By the study's conclusion, the information gathered had already been used in a number of projects concerning the Yellowstone Basin—the evaluation of applications for reservation of water in the basin, for example. Since the study's conclusion, the abundance of information compiled by all of the study's participants has been written, prepared for publication, and published. Besides the summary report you now hold, there are eleven Yellowstone Impact Study technical reports, highly detailed and prepared for the use of specialists in the involved disciplines. The eleven technical reports are listed on the inside front cover.

Sunday, July 27. The [Yellowstone] river now widens to the extent of from 400 to 600 yards; it is much divided by islands and sand-bars; its banks generally low and falling in; it thus resembles the Missouri in many particulars, but its islands are more numerous, its waters less muddy, and the current is more rapid. The water is of a yellowish-white, and the round stones, which form the bars above the Bighorn, have given place to gravel. On the left side the river runs under cliffs of light, soft, gritty stone, varying in height from 70 to 100 feet, behind which are level and extensive plains. On the right side of the river are low extensive bottoms, bordered with cottonwood, various species of willow, rosebushes, grapevines, redberry or buffalo-grease bushes, and a species of sumach; to these succeed high grounds supplied with pine, and still further on are level plains. Throughout the country are vast quantities of buffalo, which, as this is the running-season, keep up a continued bellowing. Large herds of elk also are lying on every point, so gentle that they may be approached within 20 paces without being alarmed. Several beaver were seen in the course of the day; indeed, there is a greater appearance of those animals than there was above the Bighorn.

From the *Journals of Lewis & Clark*, 1806.

THE YELLOWSTONE RIVER BASIN



(Clockwise from top) Pompey's Pillar; Lower Yellowstone Project, circa 1907; Lt. Col. George Armstrong Custer; Custer Battlefield National Monument; Chief Joseph of the Nez Perce.

ITS HISTORY

Say "Yellowstone" to someone from Lansing, Michigan, or Anaheim, California, or St. Louis, Missouri, and you'll probably remind him of a family vacation taken years ago to a famous national park full of bears and geysers. That's Yellowstone, all right, and on the strength of that fame alone nearly everyone in the United States is aware, however vaguely or inaccurately, of that region of Montana and Wyoming called the Yellowstone Basin. But the Yellowstone River and the basin that it drains have touched the lives of most Americans in more ways than one, and a good example is the history of the westward expansion of young America.

Of course, the history of man in the basin goes back much further. After the ice-age glaciers receded and the climate warmed, ancient man began to leave traces—scrapers, chopping tools, weapon points, evidence of campfires. Mass folk movements beginning about 600 years ago left the Indian tribes of the Great Plains approximately where they were when they first met the white man.

In 1806, while fellow explorer Meriwether Lewis floated down the Missouri, Captain William Clark came down the Yellowstone, putting in around Livingston after crossing the Bridger Range near Bozeman Pass. Accompanied by Sacajawea, her son Pompey, and a few other members of the expedition, he travelled in a cottonwood log dugout, hollowed with tools and fire. Captain Clark rejoined Lewis where the Yellowstone meets the Missouri. A year later, one member of the party, fur trader John Colter, returned to the region and explored the Yellowstone Plateau; his tales of bubbling mud and of geysers spewing boiling water earned the plateau the name "Colter's Hell."

It wasn't to see geysers that the fur traders swarmed to the basin over the next decade. Less than forty years after William Clark carved his name on Pompey's Pillar, steamboats were pushing up the river for their loads of furs.

Then came the gold seekers. And they found it—at Bear Gulch near Gardiner in 1866, at Cooke City in 1868. None of the Yellowstone Basin strikes proved to be as lucrative as those at Virginia City and Helena, but the miners stayed anyway—and homesteaded.

It was in 1870 that Nathaniel Langford, Henry Washburn, and Lt. Gustavus Doane sat by the fire at their last camp before leaving the Yellowstone Plateau and thought over what they'd seen. Theirs had been the first serious investigation of the fantastic tales of the mountain men about the plateau—and they had discovered that the mountain men were right. The prevailing idea in America at the time was that all of the American wilderness should be open to claim by individuals, and the three men, smoking their pipes and listening to the coyotes howl, had a hard time deciding what should be done. Finally, they agreed: the plateau was too important to be carved into homesteads. In 1872, with Langford's prodding, Congress established the first national park in the world—Yellowstone.

The Yellowstone Basin played its part in the war between the whites and the Indians. In 1876, Lt. Col. George Armstrong Custer accompanied a campaign to round up hostile Sioux and Cheyenne, who had left their reservation to join Chief Sitting Bull, a medicine man who was preaching revolt. Custer and five troops of his regiment, totaling over 260 men, were overwhelmed and killed on the Little Bighorn on June 25. A field general of the Oglala Sioux in that battle was a man named Crazy Horse.

A year later, along Canyon Creek north of Laurel, the 7th Cavalry attacked Chief Joseph and his Nez Perce band, who had just crossed the Yellowstone Plateau after the Battle of the Big Hole. The Nez Perce escaped, only to be forced to surrender three weeks later at the Battle of the Bear's Paw, where Joseph said, "From where the sun now stands, I will fight no more forever."

With the Indians forced onto reservations, settlement of the basin began in earnest. The settlers came first by wagon, on the trails pioneered by Jim Bridger and John Bozeman, and later by rail. In 1880, Thompson McElwrath wrote optimistically in **The Yellowstone Valley, a hand-book for the tourists and settlers** that the railroad's "irresistible civilizers" had opened what he saw as a treasure house: "Men have become rich almost before they could realize how wonderfully the profits multiply in a region where food and shelter for their herds cost nothing." The buffalo were annihilated by the hundreds of thousands to make room for the white man's cattle. Twenty-five years after the Battle of the Little Bighorn, the Yellowstone River's water was being diverted into irrigation canals.

Who can deny the importance of these people and these events in the settling of the West? Yet the basin's future may be as important to America as its past. The Yellowstone Basin has coal.

ITS RESOURCES AND ITS PEOPLE

Try to imagine the typical Yellowstone Basin scene—what do you see? The river? What part? The Yellowstone has its headwaters in Wyoming. Melting from snowpack on peaks over 10,000 feet high, the streams that will eventually form the Yellowstone River are cold and pure and rush rapidly downward from their alpine origin to the valley floor at around 4,000 feet. Small wonder that the trout waters of the upper Yellowstone Basin are nationally renowned. Is it the mountain stream crashing through boulders that you see? From there downstream, until the river leaves Montana, the drop in elevation becomes much more gradual; the river broadens, slows, meanders, and changes into a warm-water fishery of paddlefish, catfish, sauger, and shovelnose sturgeon. Is it the broad river of the plains that you imagine when you think of the Yellowstone?

The search for the typical Yellowstone Basin landform is no less varied. Maybe you think of agricultural land. Sideroll sprinklers with their white spray backlit by a cool morning sun, cattle and antelope sharing vast miles of dry, sparse range, green hayfields along the river—the Yellowstone Basin has all of these. Statewide, about two-thirds of Montana's land is used for agriculture. In the Yellowstone Basin the percentage is much higher. And besides using more land than any other industry, agriculture uses more water. About 92 percent of the total amount of water withdrawn in the Yellowstone Basin is for irrigation.

Or maybe it's the Absaroka Range or the Crazy Mountains you see. If so, at what time of year? Winter snowfall sometimes reaches 300 inches in those mountains. Although the plains get less snow, their winter temperatures are often even lower.

Now imagine the typical Yellowstone Basin resident. A rancher? Possibly—the livestock industry contributes more heavily than farming to agricultural income in the basin. But, like the rest of the state, the Yellowstone Basin now has over 50 percent of its population living in urban communities, rather than in rural areas. Yellowstone County is one of the three most heavily populated counties in the state, and contains the largest city, Billings, with about 70,000 people. All the principal urban centers in the Yellowstone Basin are situated along waterways, either on the mainstem or on its tributaries. Settlements originally occurred either because of arability of the land and the availability of water for irrigation and for municipal use, or as service centers for the railroads.

What do the basin's residents do for a living? One-fourth of Yellowstone County's work force, the largest group, is in the service industries; retailing is second numerically, and agriculture third, followed by construction and manufacturing. Billings now serves as a shipping center for much of the region's drilling and mining equipment.

ITS CONTROVERSIAL FUTURE

So: Agriculture is a major industry in the Yellowstone River Basin and the largest water user. And it is expanding. Elsewhere in this report, it is projected that irrigation may increase by as much as 237,000 acres by the year 2000. If it does, another 475,000 acre-feet of Yellowstone Basin water will be used up annually for irrigation, in addition to the 1.5 million acre-feet per year of water already consumed for that purpose.

Irrigated agriculture is not the only water use expected to increase. The **North Central Power Study**, released by the U.S. Bureau of Reclamation and the North Central Power Study Coordinating Committee in 1971, was probably the first major report to project massive coal development in Montana. That study identified forty-two potential power plant sites in the five-state (Montana, North and South Dakota, Wyoming, and Colorado) nor-

thern Great Plains region; twenty-one of them are in Montana. These plants, all to be fired by northern Great Plains coal, would consume 3.4 million acre-feet of water per year.

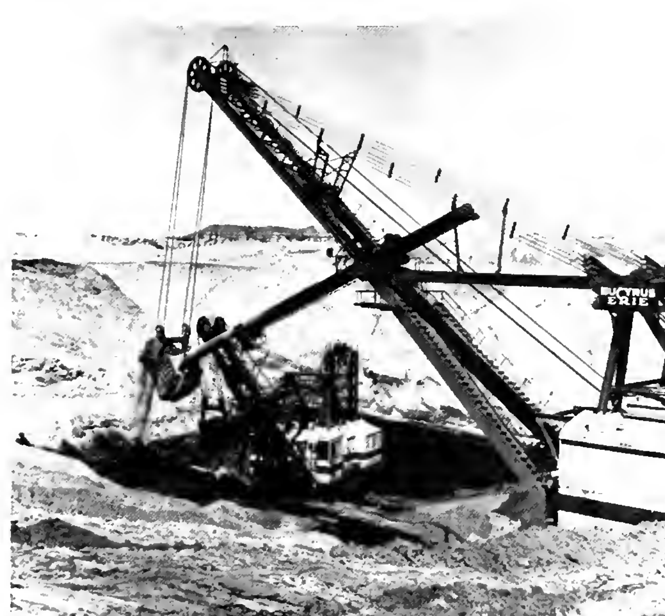
Other studies followed, projecting less development. Then in July of 1979, a U.S. Department of Energy study (**Environmental Analysis of Synthetic Liquid Fuels**) concluded that, in Montana, ten Yellowstone Basin counties provide "siting opportunities" for thirty-six synthetic fuel plants. These plants would require 468,000 acre-feet of water annually. Although it's unlikely that that many plants will actually be proposed in the foreseeable future, coal gasification and liquefaction plants may eventually demand as much water in the basin as coal-fired power plants.

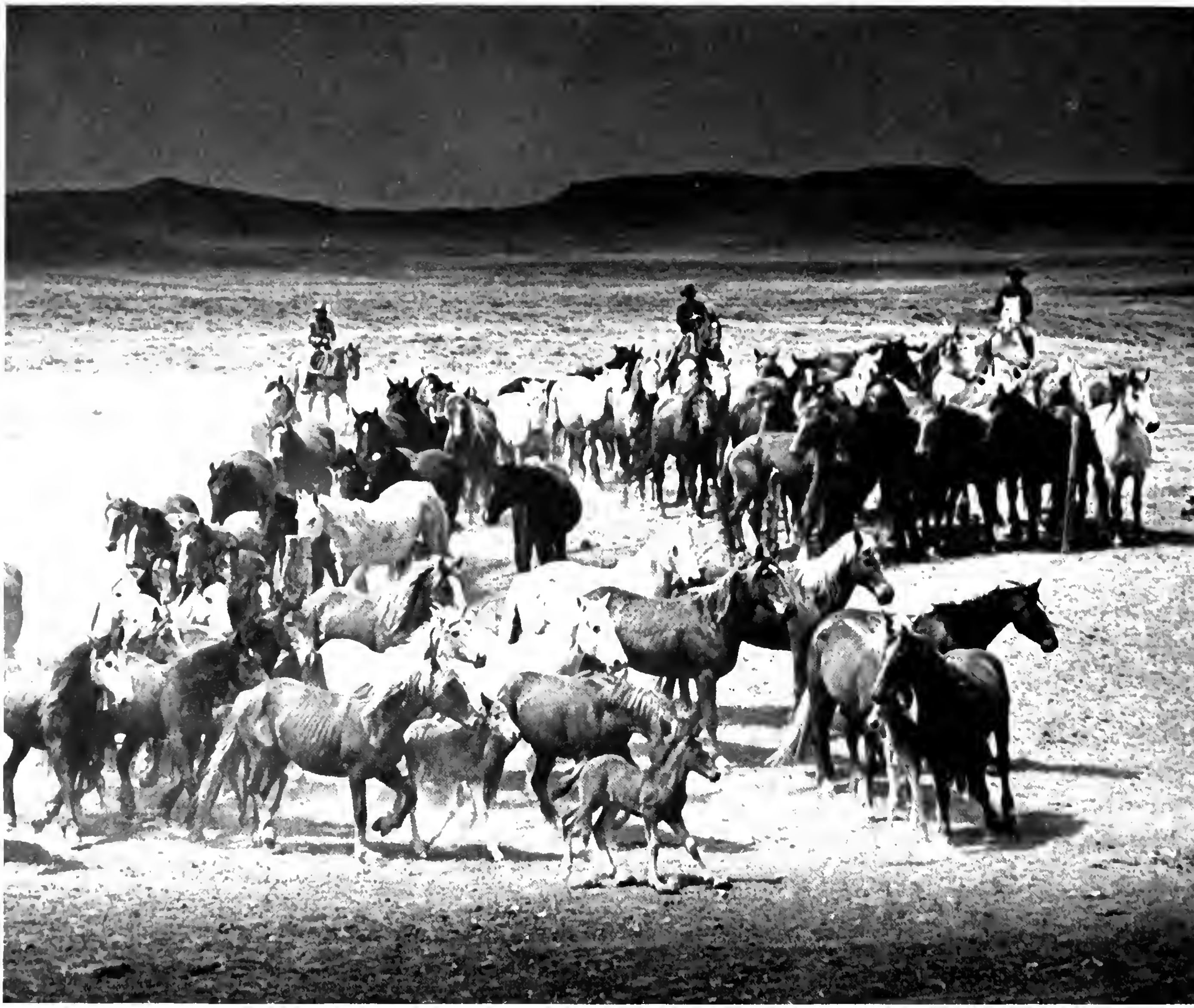
Actual power plant construction has been much slower than any of the studies, even the most conservative, projected. Colstrip Units 1 and 2, producing a total of 700 megawatts, are now finished and on line. Colstrip Units 3 and 4 were approved in 1976 by the Montana Board of Natural Resources and Conservation. Construction began in the fall of 1979, and in April 1980, lawsuits challenging the plants were dropped.

No other applications for coal conversion facilities in the Yellowstone Basin have yet been received by DNRC, although interest in such development, particularly of synthetic fuels, is still high. Even so, coal development is no longer just a prediction in the Yellowstone River Basin—it is a fact. In 1979, over 32 million tons of coal were mined in the state, up from 22 million in 1975, 11 million in 1973, and 1 million in 1969. Almost all of Montana's coal is mined in the Yellowstone Basin. By 1985, Montana's annual coal production may exceed 50 million tons. Montana coal reserves are estimated at over 50 billion economically strippable tons.

Strip mining involves little use of water. How important the energy industry becomes as a water user in the basin will depend on: (1) how much of the coal mined in Montana is exported, and by what means, and (2) by what process and to what end product the remainder is converted within the state.

Can the Yellowstone River satisfy all of these demands for her water? That's hard to answer. The Yellowstone itself is a large river and can probably provide for any





reasonable demand. But the tributary basins, especially the Tongue and Powder, have much smaller flows, and it is in those basins that much of the increased agricultural and industrial water demand is expected.

And, even though the Yellowstone mainstem could provide water for development, some impacts would result. What would happen to water quality after massive depletions? How would a change in water quality affect existing and future agricultural, industrial, and municipal users? What would happen to fish, furbearers, and migratory waterfowl that are dependent on a particular level of instream flow? Would the river be as attractive a place for recreation after dewatering?

One of the first manifestations of Montana's growing concern for water in the Yellowstone Basin and elsewhere in the state was the passage of significant legislation. (Federal and state laws affecting water use in the basin are summarized in the appendix.) The Water Use Act of 1973, which, among other things, mandates the adjudication of all existing water rights and makes possible the reservation of water for future beneficial use, was followed by the Water Moratorium Act of 1974, which delayed action on major applications for Yellowstone Basin water for three years; that period was later extended by legislative and court action and expired in December of 1978, when the Board of Natural Resources and Conservation acted on the applications for reservation of water in the basin. The moratorium, by any standard a bold action, was prompted by a steadily increasing rush of applications for water (mostly for industrial use) which, in two tributary basins to the Yellowstone, the Tongue and the Powder, exceeded supply. So that the state would be able to proceed wisely with the allocation of the basin's water, DNRC took advantage of the moratorium to study the basin's water and related land resources, as well as existing and future need for the basin's water. The Yellowstone Impact Study is one of the fruits of that effort.

THE YELLOWSTONE IMPACT STUDY: PROJECTIONS OF FUTURE DEVELOPMENT

Billings refineries.

The Yellowstone Impact Study, like similar studies before it, allowed for the infinite variety of potential laws, social phenomena, and acts of God that will work together to determine the impacts of future development in the basin by defining a *range* of possible development, within which the actual level eventually achieved will probably fall. Three levels of development were projected: one that seemed the least amount of development that could reasonably be expected, one that seemed the highest, and one that fell about midway between the two. These three levels were projected for three categories of consumptive water use: energy development, irrigation, and municipal water systems.

The geographically diverse Yellowstone Basin was divided into manageable units by the delineation of nine subbasins, shown in figure 1 (page 44).

WHAT'S GOING TO HAPPEN?

COAL PRODUCTION FOR ENERGY

The factors that will influence the mining of Montana's coal and its conversion to other forms of energy within the state are many, and their interaction is complex. Even so, some assumptions can be made with assurance. First, a rise in coal production is inevitable. Six companies operating in the Yellowstone River Basin have signed contracts committing themselves to an increasing rate of coal mining. Second, only if alternative sources of energy (such as the sun) or energy conservation prove to be more economically attractive than coal conversion is there likely to be any leveling off of Montana coal production within a decade.

Coal train at Decker.

The lowest projected level of energy development assumes that coal production will be limited to meeting Montana demands and supplying existing and planned coal delivery contracts. The intermediate level of development is, as explained earlier, midway between the low and the high. High-level development is an estimate of the extent to which mining and conversion of Yellowstone Basin coal reserves would be pursued if coal were used to fuel U.S. energy self-sufficiency and if its substitutes—energy conservation, oil, natural gas, nuclear power, and alternative energy sources—were unable to supply substantial shares. The three projected levels were based on coal delivery contracts held by the mining companies, projections of future energy development made by the Northern Great Plains Resources Program, and coal production data tabulated by the Montana Energy Advisory Council.

Table 1 summarizes the low, intermediate, and high levels of development for the year 2000. It shows that assuming low-level development, only the mid-Yellowstone and Tongue subbasins would be affected by coal conversion plant siting by the year 2000. Assuming intermediate-level development, the Powder Subbasin would also be affected, and with high-level development, the Bighorn and Lower Yellowstone subbasins would be affected in addition to the three listed above. Four subbasins would remain unaffected by direct impacts of energy facilities under high-level development even in the year 2000; Upper Yellowstone, Billings Area, Clarks Fork Yellowstone, and Kinsey Area.

The importance of these projections to the Yellowstone Impact Study was in helping to answer this crucial question: How much water would all of this projected activity require from the Yellowstone River and its tributaries? The amount expected to be consumed (diverted and not returned to the river) by the activity projected in table 1 is shown in table 2. Total water loss in the basin due to energy development would vary from 48,350 acre-feet per year for low-level development to 321,190 acre-feet per year for the high-level by the year 2000.

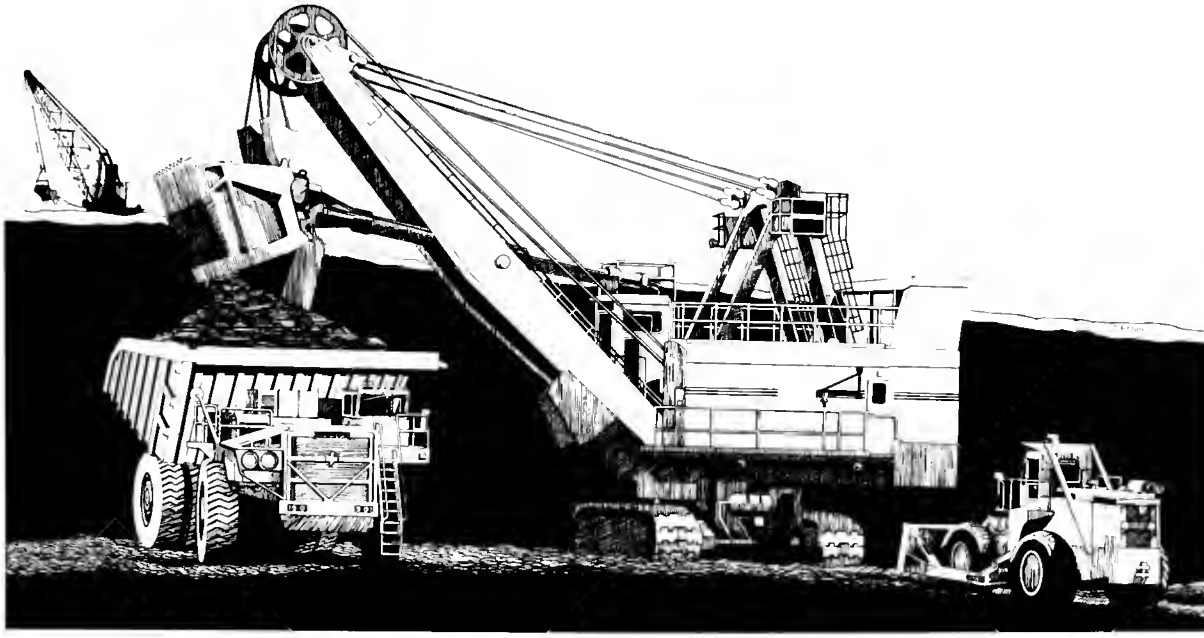


TABLE 1
Coal conversion in the Yellowstone Basin in 2000

Subbasin	Electric Generation (megawatts)	Substitute Natural Gas (million cubic feet/day)	Synthetic Crude Oil (barrels/day)	Fertilizer (tons/day)
	LOW LEVEL OF DEVELOPMENT			
Mid-Yellowstone	1,500	250	0	0
Tongue	500	0	0	0
TOTAL	2,000	250	0	0
	INTERMEDIATE LEVEL OF DEVELOPMENT			
Mid-Yellowstone	3,000	250	0	0
Tongue	2,000	0	0	0
Powder	1,000	0	0	0
TOTAL	6,000	250	0	0
	HIGH LEVEL OF DEVELOPMENT			
Bighorn	1,000	0	0	0
Mid-Yellowstone	3,000	500	100,000	0
Tongue	3,000	250	100,000	0
Powder	1,000	0	0	0
Lower Yellowstone	0	0	0	2,300
TOTAL	8,000	750	200,000	2,300

NOTE: The four subbasins not listed (Upper Yellowstone, Billings Area, Clarks Fork Yellowstone, and Kinsey Area) are not expected to include sites for coal conversion facilities.

TABLE 2
How much additional water energy development would use in 2000

Subbasin	Electric Generation	Natural Gas Production	Synthetic Crude Oil Production	Fertilizer Production	Export	Strip Mining	Total
	Increase in Depletion (acre-feet per year)						
LOW LEVEL OF DEVELOPMENT							
Bighorn	0	0	0	0	0	860	860
Mid-Yellowstone	22,500	9,000	0	0	0	3,680	35,180
Tongue	7,500	0	0	0	0	3,950	11,450
Powder	0	0	0	0	0	860	860
TOTAL	30,000	9,000				9,350	48,350
INTERMEDIATE LEVEL OF DEVELOPMENT							
Bighorn	0	0	0	0	4,420	1,470	5,890
Mid-Yellowstone	45,000	9,000	0	0	15,380	6,110	75,490
Tongue	30,000	0	0	0	9,900	7,000	46,900
Powder	15,000	0	0	0	2,210	1,670	18,880
TOTAL	90,000	9,000			31,910	16,250	147,160
HIGH LEVEL OF DEVELOPMENT							
Bighorn	15,000	0	0	0	11,100	2,050	28,150
Mid-Yellowstone	45,000	18,000	29,000	0	38,700	8,710	139,410
Tongue	45,000	9,000	29,000	0	24,860	10,170	118,030
Powder	15,000	0	0	0	5,550	2,050	22,600
Lower Yellowstone	0	0	0	13,000	0	0	13,000
TOTAL	120,000	27,000	58,000	13,000	80,210	22,980	321,190

NOTE: The four subbasins not shown (Upper Yellowstone, Billings Area, Clarks Fork Yellowstone, Kinsey Area) are not expected to experience water depletion associated with coal development.

IRRIGATED AGRICULTURE

The use of irrigated agriculture in the Yellowstone Basin has been increasing for the past few years. Forecasting the extent of further expansion of irrigated agriculture to the year 2000, like other forecasting, is risky because it must be based on a highly variable beef market, economic conditions, federal import and export policies, world eating habits, and farmer preferences—not to mention the presence of suitable land and an accessible water supply.

DNRC formulated a new set of projections of irrigated agriculture in the Yellowstone Basin, based to some degree on earlier projections. Like the projections of energy development described above, these new projections were made for three possible levels of development—low, intermediate, and high—with the intermediate midway between the low and the high. The potential increase in irrigation was estimated for 1980, 1985, and 2000, although only the year 2000 is considered in this report.

The number of acres of feasibly irrigable land—land that is irrigable considering economic feasibility as well as such physical conditions as slope, soil, and the availability of water—in each of the nine subbasins is shown in table 3.

TABLE 3
Feasibly irrigable land in the Yellowstone Basin

Subbasin	Number of Acres of Feasibly Irrigable Land
Upper Yellowstone	38,080
Clarks Fork	2,160
Billings Area	19,410
Bighorn	13,040
Mid-Yellowstone	25,230
Tongue	21,950
Kinsey Area	4,740
Powder River	75,200
Lower Yellowstone	37,670
TOTAL	237,480

DNRC assumed that the acres shown in table 3 would be irrigated under high-level development by the year 2000. Low-level and intermediate-level development would result in the irrigation of one-third and two-thirds, respectively, of the acres shown in the table. Table 4 shows the amount of water that would be consumed annually during irrigation of the projected acreage.

Low-level irrigation development of basin farmland would deplete 158,320 acre-feet per year to water 79,160 acres. Intermediate-level development would water a total of 158,320 acres and deplete the basin's water supply by 316,640 acre-feet per year. High-level development would water the entire 237,480 acres of feasibly irrigable land and deplete 474,960 acre-feet per year.

TABLE 4
How much additional water irrigation would use in 2000

Subbasin	Acreage Increase	Increase in Depletion (acre-feet/year)
HIGH LEVEL OF DEVELOPMENT		
Upper Yellowstone	38,080	76,160
Clarks Fork	2,160	4,320
Billings Area	19,410	38,820
Bighorn	13,040	26,080
Mid-Yellowstone	25,230	50,460
Tongue	21,950	43,900
Kinsey Area	4,740	9,480
Powder	75,200	150,400
Lower Yellowstone	37,670	75,340
TOTAL	237,480	474,960
INTERMEDIATE LEVEL OF DEVELOPMENT		
BASIN TOTAL	158,320	316,640
LOW LEVEL OF DEVELOPMENT		
BASIN TOTAL	79,160	158,320

NOTE: The numbers of irrigated acres at the low and intermediate levels of development are not shown by subbasin; however, those numbers are one-third and two-thirds, respectively, of the acres shown for each subbasin at the high level of development.

Center pivot irrigation plots near Fallon.

TABLE 5
Population projections for thirteen Yellowstone Basin communities by 2000

Community	1970 Population[1]	2000 Population[2] Low Level of Development	Intermediate Level of Development	High Level of Development
Miles City	9,023	15,890	16,641	20,254
Forsyth	1,873	5,189	5,664	10,249
Colstrip	200	5,044	5,824	15,107
Ashland	531	2,379	3,423	7,236
Broadus	799	4,138	6,096	10,692
Birney	13	60	70	137
Lame Deer	650	1,062	1,012	1,442
Lodge Grass	806	1,090	1,215	1,462
Hardin	2,733	4,783	5,458	7,094
Busby	300	1,160	1,038	2,036
Sidney	4,551	6,032	6,032	6,404
Glendive	6,441	8,341	8,341	8,713
Billings	63,729	94,999	95,533	98,294

[1]Baseline populations for Billings, Sidney, and Glendive are based on 1975 estimates.
[2]Includes energy industry workers and their families.

Billings subdivisions.

MUNICIPAL GROWTH

Cities and towns in southeastern Montana will demand more water as their populations increase due to energy development. (Municipal population growth in the Yellowstone River Basin presumably would be only slightly affected by agricultural development, such as expanded irrigation.) The projected population increases for the thirteen Yellowstone Basin communities expected to be affected by population increases related to coal are shown in table 5.

Table 6 summarizes the amount of additional water the communities would use. Compared to the projected depletions by energy and agricultural industries, the 11,000 acre-feet of additional water depleted for municipal use at the high level of development would be slight.

TABLE 6
How much additional water communities would use in 2000

Level of Development	Increase in Depletion (acre-feet per year)
Low	5,880
Intermediate	6,960
High	10,620

SUMMARY OF INCREASED WATER USE

Included in table 7 are the total amounts of additional depletion for all three development levels and all three categories of water use in the year 2000. For high-level development, about 807,000 acre-feet of water per year would be consumed over present levels. For the sake of comparison, about 8.8 million acre-feet of Yellowstone River water annually flows past Sidney, Montana. But that means the expected increase in depletion is less than 10 percent of the river's flow—isn't there ample water for such development, and more? Not necessarily. Yellowstone Basin streamflows are extremely variable from year to year, from month to month, and from place to place. At certain places and at certain times the water supply would be adequate. But in some of the tributaries and during low-flow times of many years, serious water availability problems would occur even under the low level of development. In planning for additional agricultural or industrial development, it is essential to know how much water is *dependable* for use, year after year. The Yellowstone Impact Study addressed that problem through computer modeling of river flows.

TABLE 7
Total increase in the water depletions in the Yellowstone Basin in 2000

Level of Development	Increase in Depletions (acre-feet per year)			
	Energy	Irrigation	Municipal	Total[1]
Low	48,350	158,320	5,880	212,550
Intermediate	147,160	316,640	6,960	470,760
High	321,190	474,960	10,620	806,770

[1]This total assumes that the same level of development occurs in all use categories.

Billings municipal water treatment plant.

HOW MUCH WATER WOULD BE LEFT IN THE RIVER?

After future energy, irrigation, and municipal development and water use have been projected, what next? To figure out how severe the impacts of all of this development would be, DNRC had to know not only how much water would be taken out of the river, but also at what times of the year it would be taken out, and how much streamflow would be left.

So a hydrologic computer model was chosen that would simulate not only the streamflow in the Yellowstone Basin under each of the projected levels of development, but also the water quality. It was on the basis of those streamflow simulations that the impacts discussed in the rest of this book were projected. The water quality simulations are discussed on pages 20 to 22.

Streamflow in the Upper Yellowstone, Clarks Fork Yellowstone, and Kinsey Area subbasins would not be seriously affected by any of the three levels of development. The Billings Area Subbasin would have enough water to meet the demands of high-level development, although flows would be reduced noticeably below historic levels during July, August, and September. Under intermediate and low levels, the subbasin could meet the demands and the river's flow would not be significantly changed.

Yellowtail Dam.

Because of Yellowtail Dam, the Bighorn Subbasin would meet its demands even under a high level of development; one year in ten there would be low flows in July and August. The intermediate and low development levels would have even less impact. The Mid-Yellowstone Subbasin could supply high-level development or intermediate-level development demands in most months, but minor shortages would occasionally occur in August.

If the demands of any of the three development levels were to be met in the Tongue Subbasin and any instream flow provided, the Tongue River Reservoir would have to be enlarged. The existing reservoir has an active storage of about 69,000 acre-feet; if that were increased to 112,000 acre-feet by raising the dam, the demands of the low level of development could be met and a minimum instream flow provided. If the capacity of the reservoir were increased to 320,000 acre-feet, the intermediate-level development water demands could be met and some instream flow provided (although, on the average, flows would be very low in August). At the high level of development, even with the 320,000-acre-foot reservoir, there would be only enough water for the proposed irrigation development, a "bare-bones" instream flow, and 28 percent of the projected energy development.

Any water development over the present level in the Powder Subbasin will require building a dam in the subbasin. The Yellowstone Impact Study simulations assumed that a reservoir with an active storage of 275,000 acre-feet would be impounded. A reservoir of this size would provide the water needed for the low level of development, but instream flows would often be low in the fall and winter. The water demands of the intermediate and high levels of development could be met with a 275,000-acre-foot reservoir. Even if only 55 percent of the irrigation development associated with high-level development were allowed, with no energy development or provision for instream flows, streamflow would often be low in the fall and winter.

In the Lower Yellowstone Subbasin, there would, on the average, be enough water to satisfy the demands of even high-level development, although streamflows would be low in August about one year in ten. In some months of extreme low-flow years, however, there would be very little water available above the amount Montanans are already using. In August 1961, for instance, there was not enough water in the river even for this study's projected low level of development.

THE YELLOWSTONE IMPACT STUDY: PROJECTIONS OF FUTURE IMPACT

Altered streamflows can affect the environment both directly and indirectly. In this case, the indirect impacts would result from changes in the river channel and in water quality. For instance, with Canada geese, it is apparently not only the size of a river or the amount of water in it that attracts them, but also the character of the river channel and banks. A change in flow that causes a change in the channel—say, a reduction in flood flows that allows vegetation to grow on previously bare banks and bars—may affect use of the river by geese and other waterfowl. Similarly, even if there is still a small amount of water available in a river for diversion by irrigators, that water will do them no good if lowered flows and upstream irrigation runoff have so increased the water's salt content that it will damage both crops and soil.

In the following presentation of potential impacts of altered streamflows, the impacts on the river channel and on water quality are presented first, since they, in turn, affect other aspects of the environment.

IMPACT ON THE RIVER CHANNEL

Among the observations recorded in William Clark's journal of his expedition was that the lower portion of the Yellowstone River (or "Rochejhone", as Clark called it, the name used by French trappers) widened and greatly increased in number of islands and bars. He is reported to have likened it to a squaw's braids, its numerous branches and backwaters winding among the islands.

The Yellowstone's braided form.

More than 170 years later, the river has retained its braided form. Of course, the river's channel has changed in that time—bars and islands have shifted, disappeared, and been formed, and once-full channels have been abandoned. In fact, changes of that type are characteristics of much of the river. Still, the braided quality of the stream has been maintained, and it is that quality that creates the varied ecosystem responsible for the diversity and abundance of wildlife found along the river. If this essential braided quality of the river were changed, the ecosystem would also change.

To understand how the river has managed to maintain its braided form despite the steadily increasing diversion of its water (irrigation now accounts for the consumption of about 1.5 million acre-feet of Yellowstone Basin water in Montana each year), and to understand why some forms of water development are potentially more damaging to the river's form than others, it is necessary to understand the concept of "bankfull discharge." Sometimes called by other names, such as "dominant discharge," this is the high flow which occurs, on the average, about two out of three years and contributes more than any other factor toward maintaining the river's form. This flow scours the channel of accumulated sediment and deposits it downstream as bars. It also washes away the plants that have taken root on the banks and bars during low flows—and it does much more. As long as the bankfull discharge occurs, a river's form should not change. So it appears to be with the Yellowstone. Because the large diversions made for irrigation generally occur after spring's high flows, they do not affect bankfull discharge; thus the river's braided form is maintained.

Bankfull discharge scours the river channel.

Speaking in terms of how it might affect bankfull discharge, thereby affecting the river's channel, streamflow alteration can be of two types: onstream storage or diversion. The more severe of the two in its effects on the river channel would be the building of dams and creation of onstream storage reservoirs on the

Core Ditch headworks near Columbus.

Yellowstone mainstem. The drastic effect that dam building has on a river's form can be seen in the changes that befell the Bighorn River after the construction of Yellowtail Dam. The Yellowstone Impact Study included a comparison of aerial photos of the Bighorn taken before dam construction with photos taken after. Even though the length of the river did not change, the total river area (including water, islands, and gravel bars) decreased by 25 percent. The area of vegetated islands decreased by 23 percent; the area of island gravel bars (gravel bars surrounded by water) decreased by a full 77 percent. The total number of islands and bars decreased by 39 percent. It is likely that a dam on the Yellowstone mainstem would have similar effects. However, the levels of development projected by the Yellowstone Impact Study would not require a mainstem dam.

The second method of streamflow alteration, diversion (either by pumping or through headgates), generally has less impact on the river channel. Even if a small diversion dam were built, the impact on the channel would be much less pronounced than the impact of a large onstream storage project because, in general, diversion does not appreciably affect the bankfull discharge. If enough water were diverted, of course, the river's form would be affected; in fact, a large enough reduction in flow could change the river's form from braided to meandering. But that would require greater reductions in flow than those projected here—at least on the Yellowstone mainstem. Remember that withdrawals would generally be more severe on the tributaries.

Although the Yellowstone's mean annual flow at Sidney would be reduced by as much as 36 percent, the bankfull discharge would be reduced only on the order of 4 to 7 percent. The river's stage (level) would be reduced only an average of about five inches at Sidney. These changes in streamflow would not bring about any change in the form of the river's channel. The reduction in the river's ability to carry sediment (from 12 percent at Sidney for low-level development to 26 percent for high), would be a more severe impact, but it is still expected that the river would be able to carry on the important sediment-carrying processes that contribute to the river's character, such as the annual scour of fine sediment from pool and backwater areas by spring's high flows.

In short, then, even though the effects of the projected altered flows on channel form can be assessed only in quality and not in quantity, it is expected that the impact would be small. History seems to support this expectation. Existing irrigation in Montana's portion of the basin annually consumes about 1.5 million acre-feet of water, almost twice the amount of additional depletion projected for high-level development. Even so, as mentioned earlier, the river's form has remained essentially unchanged since described by Captain Clark in 1806.

Because the Bighorn and Tongue rivers are already dammed and highly developed, the form of their channels would be unlikely to change.

Due to the importance of channel form to the rest of the ecosystem, the Yellowstone Impact Study established twenty-two sites on Yellowstone Basin headwater tributaries which were intensively examined, surveyed, and photographed. These sites were established as part of a nationwide system maintained by the U.S. Geological Survey called the Vigil Network. All of the information gained was filed so that at any time in the future the sites could be reexamined, the original data compared, and subtle changes in channel form, vegetation, flow, or other environmental factors detected. In this way, the Yellowstone Impact Study has contributed to the knowledge of channel form, one of the two components of the river system which, if altered, can become a means of indirect impact on the environment. A discussion of the other component, water quality, follows.

IMPACT ON WATER QUALITY

Yellowstone Impact Study investigators found that water quality in the Yellowstone River and most of its tributaries is good, especially above Billings. Below Billings, the water in the mainstem, though still of generally good quality, increases in salinity. Some of the tributaries have even higher salinity levels. One conclusion of the report was that, with few exceptions, water quality in the Yellowstone Basin declines downstream and eastward.

That decline is measured in salinity levels; salinity, can restrict a stream's use for major beneficial purposes, such as municipal supply and drinking water, irrigation, industrial operations, and maintenance of habitats for fish and aquatic life. Even now, some locations in the lower Yellowstone River have salinity levels too high for municipal supply and drinking water.

Where do these salts come from? Largely from natural sources—they're present in eastern Montana's soil. But the natural levels of salinity in Yellowstone Basin rivers and streams have been increased by man through two types of man-caused pollution sources: "point" and "nonpoint." Point sources are specific locatable conveyances such as pipes, ditches, tunnels, or wells from which pollutants are discharged. Nonpoint sources are diffuse; this type of pollution can originate from urban storm runoff, agricultural practices, road building and other construction, logging practices, and overgrazing. Of the nonpoint waste sources shown in table 8, irrigation return flows, runoff from saline seep areas, and runoff from cultivated land—all related to agriculture—contribute the greatest amount of nonpoint pollution in the Yellowstone Basin.

Point sources of pollution are adequately regulated by current water quality laws; they can be regulated because they are known. But the only legislation that presently addresses nonpoint sources of pollution in even a general manner is Section 208 of the Federal Water Pollution Control Act Amendments of 1972, which requires states to develop "208 plans" designed to identify and control both point and nonpoint sources of pollution. The pollution data now available in Montana are not sufficient to measure nonpoint pollution from individual sources.

According to the Montana Department of Health and Environmental Sciences, agricultural nonpoint discharge is the most serious water quality problem in the Yellowstone River Basin today. Irrigation practices in particular may contribute substantially to salinity levels. In diverting water to irrigated croplands, dissolved salts are

TABLE 8
Nonpoint waste sources and characteristics in the Yellowstone River Basin

Activity	Waste Characteristics
Irrigation return flows	Salinity and suspended solids, pesticides, nutrients, heat
Runoff from pasture lands	Animal wastes, sediment
Runoff from saline seep areas	Salts, sediment
Runoff from cultivated areas	Fertilizers, pesticides, dissolved salts, sediment
Storm drains and urban runoff	Oil and grease, bacteria, biological oxidizable material, suspended solids, toxicants
Construction projects, streambank riprapping	Sediment, equipment wastes
Coal mining	Salinity and suspended solids, trace elements, equipment wastes

Agricultural runoff is the most severe water quality problem confronting the Yellowstone River Basin.

also diverted to the land and concentrated through evapotranspiration; if the salt is not removed, the land may in time become too saline to grow crops. Sound agricultural practices require that all salt in the diverted water by returned to the stream through the irrigation return flow. In all likelihood, that return flow will also carry additional salt leached from the soil; salinity, or irrigation return flow may be several times higher than that of the applied water. Because of this, and because the river has less water, the salt concentration downstream from the irrigated area is increased. Each successive diversion and irrigation cycle on a stream further increases the salt concentration.

In a 1975 report, Montana's Water Quality Bureau reported that 24,700 acres in the Yellowstone Basin have irrigation salinity problems. An additional 28,000 acres of nonirrigated land are affected by saline seep. One of the report's conclusions was that "some current land uses are creating salinity problems, and, if left unaltered, will pose economic and environmental problems to future generations."

If the Yellowstone Impact Study's projections of future development are any indication, the basin's salinity problems may increase. Water quality in the Yellowstone mainstem and Bighorn River would suffer only mildly from the low and intermediate levels of projected development. (Even a mild increase could be important, though, because the upper river's good quality water is needed to dilute the salts in the lower river.) The high level of development would increase the levels of salts and other pollutants in the Yellowstone and Bighorn sufficiently to affect the plants and animals that live in or rely on those rivers, as well as their suitability for use by man.

For the Tongue and Powder rivers, the outlook is worse. *Any* future development could bring undesirable increases in salinity. Water quality deterioration in the Tongue River would be particularly high at Miles City. The reasons for the deterioration are that streamflows would be substantially reduced and salt loads from irrigation return flow would be increased. The already high levels of salinity, sulfate, and hardness would increase, and the aquatic environment would be subjected to stress by the low late-summer flows.

In the Powder River, construction of a large dam at Moorhead would cause high salinity concentrations below the dam. Use of that water for irrigation would increase the water salinity levels by two to three times before the water reaches the Yellowstone River. Water with salinity concentrations this high would be of questionable value for irrigation or municipal use.

How effective will Montana's water quality laws be in controlling future pollution? The Montana Water Pollution Control Act provides that state waters are to be kept in suitable condition for public water supply, agriculture, industrial water supply, and fishing and other recreation. "Suitability," of course, may vary considerably, depending on the primary uses of streams. For example, the degree of quality needed for stockwater is different from that necessary for man's consumption; animals can tolerate higher salinity levels than can humans. A water quality classification system developed by the state's Water Quality Bureau determines which state waters are suitable for which purposes. Further, a set of water quality standards adopted by the bureau establishes the amount of pollution allowed within each classification.

The Water Pollution Control Act includes a policy of "nondegradation," requiring that high water quality be maintained even in places where it is already well above the applicable standards. This policy is important because it means that discharges into state waters cannot significantly lower the quality of those waters. Some degradation may be allowed if the Board of Health and Environmental Sciences considers it to be economically or socially justifiable.

Application of the nondegradation policy to the practice of dewatering, which may degrade a stream by lowering its water level, may be difficult. Under present state government organization, the Department of Health and Environmental Sciences administers water quality standards, but the Department of Natural Resources and Conservation administers water appropriations and withdrawals. As a result, the only way in which the Department of Health and Environmental Sciences can attempt to regulate the negative effects of dewatering may be to apply to the Board of Natural Resources and Conservation for flow reservations.

Under some circumstances, the dewatering and polluting effects of irrigation and coal development can be great. How effective the nondegradation policy may be in the future water quality management of the Yellowstone River is uncertain. The Board of Health and Environmental Sciences has yet to adopt guidelines for determining what kinds of polluting activities would be economically or socially justifiable.

In summary, the Yellowstone Impact Study found that Montana's water quality laws are adequate and effective for control of point-source pollution, but not for control of pollution caused by nonpoint sources and dewatering. These deficiencies, unless remedied, could have serious effects on water quality in the Yellowstone River Basin. The effects of altered streamflow on water quality in the Yellowstone River Basin may be serious at the high level of development; the low and intermediate levels would, in most cases, produce only minor effects on beneficial uses and the aquatic ecosystem. The exceptions are in the Tongue and Powder rivers, where any level of development could bring serious deterioration of water quality.

Dewatering increases water quality problems.

IMPACT ON EXISTING MUNICIPAL AND AGRICULTURAL USERS

The water rights doctrine of prior appropriation still applies in Montana: first in time is first in right. In theory, then, any future increase in water use in the Yellowstone River Basin would have no effect on municipal or agricultural users with valid water rights. But, practically speaking, there is an important difference between *availability* of water and *accessibility* of water.

For example, imagine an irrigator in the lower Yellowstone Basin who has a headgate on the river to divert water into his canal, but no diversion dam. He has a water use permit with a priority date of August 1974. As long as all water rights with earlier priority dates are satisfied and there is still water in the river, that irrigator has the right to divert the amount of water specified on his permit. But suppose that, by 1985, increased upstream withdrawals of water for irrigation and energy development lower the surface of the river below his headgate. There is still water *available* to him in the river, and he has the right to divert. But, because it is now physically impossible for him to divert it into his canal, it is not *accessible* to him. Only expensive modification of his headgate and canal would make it possible to divert at the new lower river levels. Not only gravity diversions could be affected; lowering of the water surface elevation at pump intakes could, by increasing the pumping head, increase pumping costs, in both dollars and energy.

To determine any adverse effects that a decrease in the accessibility of water, as a result of reduced streamflows, would have on the existing water users in the Yellowstone River Basin, the Yellowstone Impact Study included an investigation of the diversion systems of three municipalities and a number of agricultural users. The locations of those diversions studied are shown in figure 1 (page 44).

MUNICIPAL WATER USE

Billings, Miles City, and Glendive, the municipalities studied, draw their water supplies directly from the Yellowstone River. The Yellowstone Impact Study showed that the cost of providing municipal water for Billings, Miles City, and Glendive will increase in the future, primarily because of increased water consumption due to population growth and probable increases in the price of electricity. Lowered water surface elevations, at least at the levels projected by the Yellowstone Impact Study, would have no great effect on municipal water system costs, with one possible exception. At Glendive, the municipal water intake structure might have to be rebuilt if the river level is lowered, but such rebuilding may be necessary even if there is no change in water use in the basin.

Montana Power Company plant at Billings.

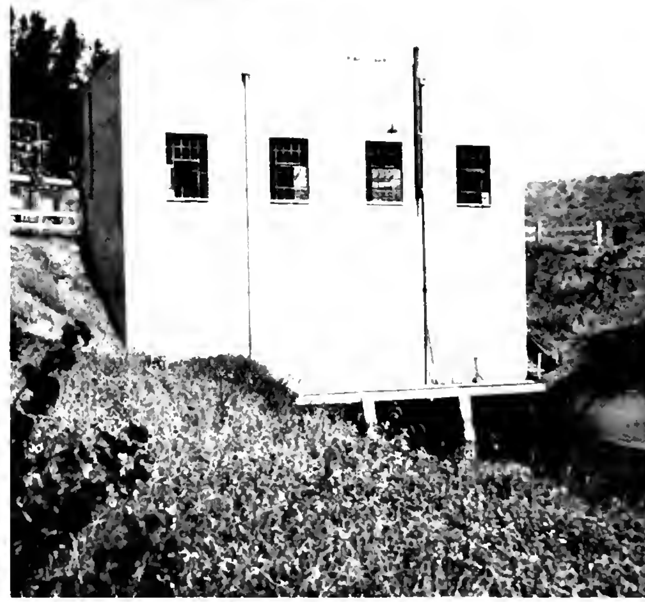
IRRIGATION WATER USE

Four pumping and twelve gravity irrigation diversions (figure 1, page 44) were examined to determine the potential effects of lowered streamflow.

The pumping diversions studied (three near Sidney and one near Kinsey) were chosen because they are located in the lower part of the Yellowstone River drainage, where (according to the Yellowstone Impact Study's projections) lowered streamflows would occur. The efficiency of these plants is already greatly reduced during extremely low river flows. In other words, when flows in the river decrease, pumping costs increase. Projected cost increases ranged from 0.2 percent over existing costs for the Sidney No. 2 pump site in June at the low level of development to 11.1 percent for Kinsey No. 7 in September at the high level.

Gravity diversion systems may be classified as *controlled* or *uncontrolled*. A controlled diversion system includes a structure across the diverted stream that allows the irrigator to control the amount of water being diverted. The uncontrolled gravity diversion system has only a headgate to divert water into the system.

Big Ditch headworks near Billings.



Glendive water pumping station at Fallon.

Three of the gravity irrigation diversions selected for study (Intake No. 4, Tongue and Yellowstone No. 8, and Forsyth No. 11) are controlled diversions. These have no problems getting water into the distribution system when river flows are low because their headgates are below the crest of the diversion dams. They would continue to operate efficiently if flows were further reduced.

Nine uncontrolled gravity irrigation diversions (seven near Livingston, one near Columbus, and one near Huntley) were studied. All have minor headgates built at the head end of canals. Most already have problems getting sufficient water during low streamflows in the Yellowstone River. Reduced flows due to increased development would aggravate these problems.

Among the solutions to most of these problems are: provision of adequate instream flow in the river; installation of permanent, impervious diversion dams in the main river channels opposite the side channels that the diversions are now on; and rechanneling the river so that most of the flow is directed toward the diversion.

Big Ditch diversion dam.

IMPACT ON FISH AND WILDLIFE

Generally, streams change from steep torrents to sluggish meandering waterways as they proceed from source to mouth. Usually there are stages between the two extremes characterized by particular environmental features and particular aquatic animal species. As river conditions change, headwater species disappear and are replaced successively by others better adapted to the changing environment. Poor water quality can upset this normal distribution. Flow alteration or excessive pollution can also disturb the fish and wildlife that depend on the river system—in fact, because of the relationships among aquatic plant and animal species, flow alteration or pollution may disturb a great many species at once. For example, if insect habitat were reduced, then the population of insect-eating fish also would suffer. In turn, a decrease in fish populations can have a detrimental effect on fish-eating bird species.

The Yellowstone Impact Study investigated the likely impacts of water withdrawals upon aquatic invertebrates, migratory birds, furbearers, and fish.

AQUATIC INVERTEBRATES

More than 170 kinds of aquatic invertebrates have been found in the Yellowstone River. Insects dominate the population. Sow bugs, water scorpions, water mites, snails, clams, and worms also live in the river.

The needs and distribution of the river's three dominant orders of insects—the mayflies, caddisflies, and stoneflies—were studied at twenty sampling stations along the river. Diversity and density are greatest in the upper river, decreasing downstream.

A decrease in flow that results in a reduction of current velocities would probably result in a reduction in numbers and species of invertebrates because many species prefer swift currents. Exposure of any amount of river bottom because of lowered flows would decrease the number of bottom-dwelling organisms simply by decreasing their habitat.

Normally, the high spring runoff keeps the river flushed of silt, but low discharges and reduced currents would allow greater amounts of silt to accumulate. Reduced flows would also probably result in higher summer water

Aquatic invertebrates, such as the mayfly (nymph, *top inset;* adult *bottom inset*), are an important source of food for many fish species in the Yellowstone River Basin.

temperatures, which could interfere with invertebrate egg hatching, emergence, growth, and metabolism. Again, the net result would probably be a reduction in bottom fauna.

Communities of aquatic organisms are subjected to periodic stress due to environmental changes, both natural and man-caused. As stress increases, species diversity decreases, sometimes even to the point of extinction. Altered streamflow, because it can increase stress, has the potential to significantly reduce the numbers of aquatic invertebrates in the Yellowstone River.

FISH

The Yellowstone Impact Study investigated fish habitat in the Tongue River, major sport fish in the Tongue River Reservoir, and important food sources for fish in the lower Yellowstone River.

One of seven major tributaries joining the Yellowstone River in Montana, the Tongue River supports a variety of aquatic life. It is also an important source of water for irrigation, domestic use, livestock watering, and recreation. The river and the reservoir may become increasingly important for the operation of proposed coal conversion plants.

The paddlefish, a popular sportfish in the basin, depends on free-flowing rivers like the Yellowstone for survival.

Tongue River Fishery

The Tongue River, from the dam to the mouth, was divided into five sections. Thirty-one fish species were found in those sections (table 9), and three of them—the channel catfish, the sauger, and the shovelnose sturgeon—were selected for closer study of the potential impacts of reduced flow. Those three were selected because of their sensitivity to pollution and to change in flow, under the theory that if life requirements for sensitive species are met, then requirements for less sensitive species are also likely to be met.

The channel catfish, which received game fish status in Montana in 1975, and the sauger are important game fish in the lower Yellowstone Basin. Native to Montana, both were first recorded by Lewis and Clark. The channel catfish's preferred habitats are large rivers and lowland lakes,

TABLE 9
Distribution of fishes in the Tongue River by zones, 1974 and 1975

	V	IV	III	II	I
Brown trout	*				
Whitefish	*				
Northern pike	*	*			
Yellow perch	*	*			
Black crappie	*	*			
Yellow bullhead	*	*			
Rainbow trout	*	*	*		
Rock bass	*	*	*	*	
Mountain sucker	*	*	*	*	
Pumpkinseed	*	*			*
Smallmouth bass	*	*		*	*
White crappie	*	*		*	*
River carpsucker	*	*	*	*	*
Carp	*	*	*	*	*
Stonecat	*	*	*	*	*
Shorthead redhorse	*	*	*	*	*
White sucker	*	*	*	*	*
Longnose sucker	*	*	*	*	*
Longnose dace	*	*	*	*	*
Black bullhead		*	*		
Green sunfish		*	*	*	
Channel catfish		*		*	*
Sauger		*	*	*	*
Flathead chub		*	*	*	*
Goldeye					*
Burbot					*
Walleye					*
Paddlefish					*
Shovelnose sturgeon					*
Blue sucker					*
Sturgeon chub					*
TOTAL NO. SPECIES	19	22	14	15	20

and it does not tolerate pollution. The shovelnose sturgeon is also a sensitive species. Because of its migrational patterns, it requires a particular water depth and velocity for passage and spawning.

At the low level of agricultural development, little impact would occur except during late summer, when flows would be insufficient for the channel catfish's spawning needs. Impacts would be severe at the intermediate and high levels of development all year long, resulting in loss of spawning and rearing flows necessary to maintain the sauger and channel catfish fishery. Reduced spring runoff flows would result in loss of spawning habitat for the shovelnose sturgeon.

Tongue River Reservoir

The Tongue River's flow is controlled by the Tongue River Dam and Reservoir. The Yellowstone Impact Study considered angler harvest of major sport fish in the reservoir and the effects of large water withdrawals on fish populations.

The Tongue River Reservoir provides a healthy, reproducing fishery in an area with low human population. Creel censuses indicate that the reservoir is only lightly fished. Black and white crappie are the most abundant sport fish in the reservoir, and popular targets of fishermen. Other major sport fish in the reservoir, in order of harvest frequency, are the walleye and sauger, northern pike, and smallmouth bass. The warm, weedy bays preferred by northern pike are rare. Largemouth bass live in the reservoir, but are rarely taken by fishermen. Smallmouth bass are becoming important as sport fish.

The three levels of development considered in this report would require no serious changes in storage patterns of the reservoir, and impacts on the Tongue River Reservoir's fishery also would be minimal (although as population increases in the Decker area, fishing pressure is expected to increase).

Food Habits in the Lower Yellowstone River

The lower Yellowstone provides a variety of habitats, including shallow and deep riffles, pools, and still backwaters. This diversity allows for a diverse aquatic community. Of the forty-nine fish species in the Yellowstone River, forty-five are present in the lower river; twelve species are game fish.

These fish species feed on forage fish and on the more than seventy species of invertebrates present in the lower Yellowstone. To determine how important these food sources are to fish, the Yellowstone Impact Study, during 1974-76, examined the food habits of the shovelnose sturgeon, goldeye, channel catfish, burbot, and sauger.

Aquatic insects were found to be highly important in the diets of sturgeon, goldeye, and catfish; the sturgeon's entire diet consisted of the bottom insects found in riffles. The goldeye fed exclusively on insects as well, including some terrestrial insects. And, although catfish ate some forage fish, insects were also important in the catfish diet. For the most part, young sauger and burbot ate invertebrates.

Reduced discharge could reduce food sources for fish by affecting riffles and backwaters, the main habitats of insects and forage fish. Riffle insects rely on specific current velocities for food, oxygen, and protection from predators; reduced discharge would not only reduce velocities, it would also reduce the wetted bottom area of the channel. The backwater areas where mature sauger, burbot, and catfish catch their supply of forage fish would be rendered less productive if the river's high spring flows were reduced.

Excessive water withdrawals made during August and September, when the growth rate of most aquatic organisms is greatest, would cause the most severe impacts on aquatic communities.

MIGRATORY BIRDS

The north-south migration routes of waterfowl and other bird species cross the Yellowstone River between Billings and the North Dakota border, and the migrating birds often stop to feed in grain fields near the river. Canada geese banded along the river have been recovered as far away as Saskatchewan and northern Colorado; geese and ducks harvested by hunters in the basin during the study had been banded in Alberta, North Dakota, Colorado—even New Mexico. But for some species, the Yellowstone is more than a stop on the way somewhere else—it is home. Canada geese and other species nest and rear their young along the river; some winter there. To assess the importance of the river to migrating, breeding, and wintering birds, and to determine the potential impact on those birds due to altered streamflow, Yellowstone Impact Study biologists observed the activities of migratory birds on the river from September 1974 through November 1976. Researchers spent more time and effort studying Canada geese than any other species. The reasons are many: they are present in the study area year-round; they nest and rear their young along the free-flowing Yellowstone mainstem, rather than on ponds and other off-river sites, as do most ducks; large numbers migrate through the basin each spring and fall; they are a favorite game bird. Also studied were mallards, which are present in the study area in even greater numbers than geese. They, too, winter on the river. Other duck species observed included mergansers and goldeneyes. Great blue herons, bald eagles, white pelicans, double-crested cormorants, ospreys, and sandhill cranes were studied.

Throughout the year, geese feed mostly in grain and hay fields along the river—most commonly, fields of barley


Snow geese and other migratory waterfowl stop off to feed in grain fields along the river.

stubble and corn cut for silage. Mallards also feed on these crops, as well as on wheat stubble, but seem to prefer picked corn fields.

In some ways, increased water development in the basin may benefit migratory birds. Increased irrigation along the river, particularly circular sprinkler irrigation may attract more migrant field-feeding ducks and geese in spring and fall. Waterfowl might temporarily benefit if lowered streamflows were to uncover more unvegetated area along the river bank. Unvegetated bank is used extensively by ducks and geese for "loafing," and after dewatering, the distance of the birds from the streamside vegetation where predators can conceal themselves would increase. That benefit would be only temporary if vegetation were to become established on previously bare banks and bars. Another possible temporary benefit would be the stagnation of some backwaters, which could result in increased duck brood-rearing habitat until the areas filled with silt and became vegetated.

Not all of the effects of altered streamflow would be good for migratory birds, not even temporarily. Goose nests are usually constructed on islands at relatively vegetation-free sites. In 1976, when low flows in spring allowed greater-than-average predator access to the islands, more than half of the nests in some areas were destroyed by predators, especially raccoons. Flow reductions that eliminate side channels (thereby eliminating islands) or reduce the width and depth of channels would make it easier for predators to raid nests and endanger loafing geese. Likewise, any changes in flow (such as impoundment in reservoirs or significant flow reduction) that allow vegetation to establish itself on bars, banks, and high-water channels would impair goose nesting in those areas. Altered silt deposition and ice scarification patterns would also allow advancement of vegetation, with similar results.

Ducks don't usually nest along the river; thus, their nesting habits would be unaffected by flow alteration. Since ducks use the same open bars and banks for loafing that geese do, increased predator access to these areas or encroachment of vegetation upon them would be as unsuitable for ducks as for geese.

A prolonged flow reduction would eventually result in a reduction in fish habitat, causing a reduction in fish populations in the river. Finally, of course, the populations of fish-eating birds, such as mergansers, pelicans, cormorants, ospreys, and herons would decrease as well.

FURBEARERS

Many furbearing animals live along the Yellowstone River, but only three—beaver, mink, and muskrat—depend on the river for habitat and food. Other furbearers, like coyote, fox, raccoon, and bobcat, frequent the mainstem but don't depend on a riverine environment for survival. Yellowstone Impact Study researchers tried to find out which species were present along the river, their relative abundance, and important habitat types. They then assessed the flow-related impacts on each species and on the supplemental income of trappers.

The beaver is the furbearer most dependent on the river. The braided sections of the Yellowstone, with many islands and abundant willow and young cottonwood stands, provide the best beaver habitat. Beaver live either in a bank den or in a lodge with an underwater entrance. They build caches of branches for a winter food supply by trimming willow and cottonwood branches and piling them to sink. These caches remain unfrozen throughout the cold winter months when ice covers the stream or river.

High flows in winter can cause loss of caches and lodges through flooding, leaving the beaver without shelter or food at the time when it is most difficult to obtain them. Lowered flows can expose the entrances of lodges and dens to predators, and also uncover, thereby exposing to freezing, caches that normally would remain below water level, where they would be easily accessible.

Extremely lowered flows on the Yellowstone in the fall would encourage dam building, something that beaver could not normally do on the Yellowstone, Tongue, or Bighorn rivers. To build dams, beaver would cut cottonwoods trees and willow stands, thus decreasing the available food supply, weakening bank resistance to erosion by high water during runoff periods, and reducing habitat for other wildlife species that use the cottonwoods and willows for nesting, perching, and protective cover.

Of all possible types of development, dams would cause the most severe detrimental effects on furbearers, especially beaver. Flow changes following the construction of Yellowtail Dam altered the Bighorn River's morphology from that of a braided river with many islands and abundant stands of willow and young cottonwood to a less braided stream with one-third fewer islands. A similar change on the Yellowstone would reduce furbearer habitat.

Muskrat may den in banks or build houses on lakes and marshes. Unlike beaver, they feed on a variety of plants, including cattail and bullrush. Lowered streamflow in winter can cause their food supply to freeze, resulting in an increase in disease and death.

Mink live along streams and lakes where they feed on small mammals, birds, eggs, frogs, crayfish, and fish. Because they often wander long distances from water in search of food, they are less dependent than beaver on the river.

Most of the trappers in south central Montana live on the mainstem of the Yellowstone, and more live in Billings than any other single location. Nearly $215,900 was introduced into the area economy from the sale of pelts by licensed trappers in the 1973-74 season. The average licensed trapper in the study area realized $685.

Since the 1960-61 season, beaver have been the most economically important species. Since that season, the sale of beaver pelts has generated an average annual income of about $200 per beaver trapper. Mink pelt sales follow with an average of about $80.00 per trapper. Muskrat trappers realized less.

Beaver and muskrat pelt prices have little effect on the number of beaver trapped, suggesting that trappers are as interested in recreation as in profit. Increases in mink pelt prices, however, seemed to increase the number of mink trapped throughout the study area.

Beaver lodge.

IMPACT ON RECREATION

Recreation and tourism are both a business and a way of life in Montana. How many residents came here—or stay here—for the fishing, the hunting, the clean air, the unbroken and unspoiled countryside to roam in? How many Montanans earn at least part of their living providing services to those who drive to Montana from Minnesota or Kansas every year for recreation? The Yellowstone Impact Study investigated the types of recreational use now taking place along the river, and projected what changes might take place if more water is withdrawn for other uses.

Concerning existing recreational use, the Yellowstone Impact Study attempted to answer two questions: Who is using the Yellowstone River? And in what ways are they using it?

There were no real surprises in the answers to the first question. According to a survey conducted by Yellowstone Impact Study workers in 1975 and 1976, about 80 percent of the river's recreational users were Montanans from the nearest city. About 70 percent didn't consider themselves to be on vacation. Blue-collar workers and retired people predominated.

That survey also helped answer the second question. Again no real surprise. If you see someone stop his car along the Yellowstone River and get out, chances are you'll guess he's going to fish. And chances are you'll be right; over half of the recreationists surveyed came to fish. They fished for trout, sauger or walleye, and catfish, in that order. (The survey was given *after* the peak paddlefishing period.) Thousands fish for huge, spoon-snouted paddlefish on the lower river in spring; about one thousand people visit the Intake Fishing Access site each day in May.) The Bighorn and Tongue rivers also offer fishing. Over half of those surveyed came to the river just for the day. Seventeen percent brought boats.

The results of that survey didn't really illustrate the diversity of recreation along the Yellowstone. Many recreationists come to the river just to relax, to see the sights. Many others come to the lower river to hunt for agates. Swimming in the river is most popular around Billings and further upstream. Many people hunt along the river for big game, game birds, and waterfowl. Several organized boat floats take place on the river or its tributaries every year.

Since recreation in the Yellowstone River Basin is as popular as it is, the second part of the study—projecting how lowered streamflows might affect recreation—was of great importance.

The annual Yellowstone River Float draws recreationists from many areas.

Altered streamflows would least affect shoreline recreation, although the river could become less scenic as water withdrawals increase. Fishing, by far the most popular river use, would be seriously threatened by substantial water losses. Certain levels of streamflow are essential to hatches of some types of insects that fish feed on, and water depth is directly correlated to fish population and habitat. Paddlefishing would suffer drastically if levels were reduced, affecting the migration pattern and spawning habitat of these large fish.

A large proportion of those queried in this study enjoyed boating and other water-based sports. Any drop in water levels or water quality would severely curtail these uses. Water skiing, floating, and swimming would all be adversely affected by the extensive water withdrawals foreseen at the intermediate and high levels of development. At some parts of the river, passage would be impossible.

Many of those responding to a study questionnaire expressed the need for more recreational sites along the Yellowstone. Increased use growing out of population expansion would place added pressures on existing sites and make the acquisition and development of more sites necessary.

Recreation is a vital part of Yellowstone River usage and must be considered important, socially as well as economically, to Montana and its neighboring states.

ECONOMIC IMPACT

Economists deal in *costs* and *benefits*. A simplified view of an economic analysis is that if the benefits exceed the costs, the action makes sense economically. If the costs exceed the benefits, it does not.

Cost is defined by economists as any losses that people incur as a result of a proposed action, whether or not dollar values have been assigned to those losses. In that sense, all the potential environmental impacts discussed on the previous pages—impacts on water quality, fish and wildlife, existing water users, recreation, and the river channel itself—should be considered as costs of increased withdrawals. Although it is difficult to assign a dollar value to those impacts, their importance in the ratio of benefits to costs is undeniable. These impacts must, by law, be considered before any action is taken by the state of Montana that will significantly affect the river.

The benefits of increased withdrawals (in this case, the economic effect on farmers of maintaining a specific level of instream flow*) are more easily estimated.

The Yellowstone Impact Study concluded that the level of instream flow considered here would decrease agricultural profits in the basin in the year 2000 by less than 1 percent. If less water were reserved (in December 1978, the Board of Natural Resources and Conservation did, in fact, reserve considerably less water for instream flow than the Yellowstone Impact Study considered), the decrease in profits would be even less. Montana's prior-appropriation doctrine will insure that instream reservations will have no effect on agricultural water users with "senior" water rights—those that predate the reservations. And because the instream flow constraints would reduce the number of irrigated acres only in August and September, and would reduce only the amount of water available for irrigating pastures (farmers would irrigate their high-return crops with the available water), the marginal value to irrigators of the water reserved as instream flow is low. (In economic jargon, "marginal" does not mean "doubtful." Instead, it refers to only that portion of the costs or benefits that accrues as a result of an incremental increase in something—in this case, an increase in the supply of water.) The instream-flow levels considered in this study would not seriously restrict irrigated agriculture in the Yellowstone Basin.

Another way to compare the costs and benefits of water withdrawals is to compare the value of water left in the stream for nonconsumptive (instream) purposes with the value of water withdrawn for consumptive use. The principal instream uses in the Yellowstone Basin are recreation, maintenance of the aquatic and streamside habitats, and water quality control. Water withdrawals in the basin are principally made for agricultural, municipal, and industrial uses.

Two principles govern the allocation of water between instream and out-of-stream uses. First, the value of additional withdrawals is subject to diminishing returns. For example, when only a small quantity of water is available

*The level of instream flow used in the study was the level requested for the Yellowstone River and tributaries by the Montana Fish and Game Commission in October 1976 as a reservation of water under the Water Use Act of 1973.

Buffalo Rapids irrigation project near Terry.

for irrigation, it is used on fertile soils close to the river and only for high-value crops. Because costs for this type of irrigation are low and revenues are high, the value of the first increments of water is high. Additional increments of water are less productive because the costs of pumping it to less desirable lands farther from the river increase and revenues decline as the markets for high-value crops become saturated and lower-value crops are grown. In other words, when water is in short supply, the value of additional water to farmers (the price they would be willing to pay) is high—but when water is abundant, the price farmers would pay for more water is lower.

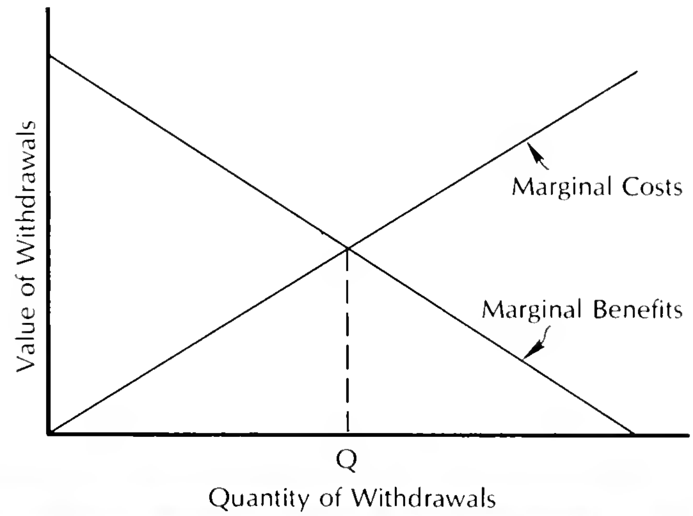
The second principle is that withdrawals reduce the value of uses and activities that depend on instream flows. Unlike the value of additional withdrawals to irrigators, which decreases with each increment of withdrawal, the effect on instream uses of each succeeding increment of withdrawal does not decrease. In fact, for some environmental concerns such as water quality, the degree of loss *increases* with succeeding increments of withdrawal.

The relationship of these two principles is shown in figure 2, a simple graph plotting the *value* of withdrawals against the *quantity* of withdrawals. The line marked "marginal benefits" represents the first principle; the first withdrawals are of high value, but, as the quantity of withdrawals increases, their value decreases, giving the line a negative slope. The line marked "marginal costs" represents the second principle; the first withdrawals,

especially if they are small, have little negative impact on instream uses of water, but, as the quantity of withdrawals increases, their relative impact on instream uses also increases, giving the line a positive slope. Even if this second line were horizontal, implying that the effect on instream uses of each increment of withdrawal would be equal to the effect of the previous increment, the significance of the graph would not be altered, and that significance is that the two lines cross. The point at which they cross shows the level of withdrawal (Q) at which the benefits of withdrawals equal the costs of withdrawals—that level is the best allocation of water between instream uses and withdrawals.

Determining where point Q is—that is, determining how much water could be withdrawn under the best allocation between instream uses and withdrawals—is difficult, and the Yellowstone Impact Study did not find that point. The important thing is that the point exists. In short, there is a particular level of withdrawals at which the costs of further withdrawals would exceed the economic benefits; when that point has been reached, it is neither environmentally nor economically desirable to appropriate any more of the river's flow.

FIGURE 2
Relationships of withdrawals to cost and benefits



SUMMARY

Makoshika badlands.

Even if the Yellowstone River Basin had nothing else to offer, it would be known as an area rich in the history of our nation's childhood. The roster of those who shaped the settling of the basin reads like a list of the all-stars of the West: Lewis and Clark, Sacajawea, John Colter, Jim Bridger, Calamity Jane, Sitting Bull, Crazy Horse, Lt. Col. George Armstrong Custer, Chief Joseph of the Nez Perce. And the basin is valuable for more than its history. Take recreation, for example. Besides the nation's foremost national park, the basin possesses a major wilderness of over 900,000 acres, blue-ribbon trout streams of national renown, and a great variety of other recreational opportunities for both residents and visitors. Or consider its economic importance to the state. Billings, Montana's largest city, is in the basin. The basin's agriculture and energy (mostly coal development) industries contribute substantially to the state's basic industrial income. Neither agriculture nor the energy industry has reached maximum development in the basin. As they expand, the basin's population will also expand.

Much of the water that will be used for these three types of development—agricultural, industrial, and municipal—will have to come from the Yellowstone's tributaries, and some, like the Tongue and Powder rivers, have little if any to spare. At some times of the year, especially during dry years, even the Yellowstone mainstem has little water available.

So the Yellowstone Impact Study was proposed by the Montana Department of Natural Resources and Conservation and funded by the Old West Regional Commission. Its purpose was to evaluate the potential physical, biological, and water use impacts of water withdrawals and water development on the middle and lower reaches of the Yellowstone River Basin in Montana. The study first projected three possible levels of future agricultural, industrial, and municipal development in the Yellowstone Basin and the streamflow depletions associated with that development. Then, researchers assessed the effects of those depletions on the river channel, water quality, migratory birds, fish, aquatic invertebrates, furbearers, recreation, and existing water users. The study resulted in this summary report and in eleven specialized technical reports.

PROJECTIONS OF FUTURE DEVELOPMENT

The important part of the projections was not how many tons of coal would be exported or how many acres irrigated, but rather how much water would be used. The development and water use projections for the year 2000 are summarized in tables 10 and 11.

When the projections of future water use were completed, the effects of that water use on water supply in the basin were determined. The Yellowstone mainstem and the Bighorn River would be able to meet even the demands of high-level development, although summer and fall flows would be extremely low in the mainstem as a result. Neither the Tongue nor Powder rivers would be able to supply the water demanded of them under high-level development.

TABLE 10
Increased water requirements for consumptive uses in the Yellowstone Basin in 2000

Level of Development	Irrigation: Acreage Increase	Irrigation: Increase in Depletion (af/y)	Municipal: Population Increase	Municipal: Increase in Depletion (af/y)	Energy[1]: Increase in Depletion (af/y)	Total Increase[2] in Depletion (af/y)
Low	79,160	158,320	56,858	5,880	48,350	212,550
Intermediate	158,320	316,640	62,940	6,960	147,160	470,760
High	237,480	474,960	94,150	10,620	321,190	806,770

[1]Details of the water requirements for energy use are shown in table 11.
[2]This total assumes that the same level of development occurs in all use categories.

TABLE 11
Increased water requirements for coal development in the Yellowstone Basin in 2000

Level of Development	Electric Generation	Gasification	Syncrude	Fertilizer	Export	Strip Mining	Total
			COAL MINED (mmt/y)				
Low	8.0	7.6	0.0	0.0	171.1		186.7
Intermediate	24.0	7.6	0.0	0.0	293.2		324.8
High	32.0	22.8	36.0	3.5	368.5		462.8
			CONVERSION PRODUCTION				
Low	2000 mw	250 mmcfd	0 b/d	0 t/d			
Intermediate	6000 mw	250 mmcfd	0 b/d	0 t/d			
High	8000 mw	750 mmcfd	200,000 b/d	2300 t/d			
			WATER CONSUMPTION (af/y)				
Low	30,000	9,000	0	0	*	9,350	48,350
Intermediate	90,000	9,000	0	0	31,910	16,250	147,160
High	120,000	27,000	58,000	13,000	80,210	22,980	321,190

*No water consumption is shown for export under the low level of development because, for that development level, it is assumed that all export is by rail, rather than by slurry pipeline.

PROJECTIONS OF FUTURE IMPACT

The potential impacts of altered streamflow on the river channel and on water quality were projected first, since they in turn affect other parts of the environment.

Impact on the River Channel

The braided form of the lower Yellowstone mainstem, composed of numerous branches among the islands and bars, is one of its most important environmental characteristics. Changing that form would change the ecosystem. The water use projected by the Yellowstone Impact Study would not change the form of the Yellowstone mainstem because there would be no significant effect on the combination of flood flows and sediment-carrying ability that shapes the river's channel. A dam would be necessary on the Powder at any of the three projected levels of development, and its construction would cause considerable erosion downstream.

Impact on Water Quality

The effects of altered streamflow on water quality in the Yellowstone River Basin may be serious at the high level of development, particularly in the Tongue and Powder subbasins and, to a lesser degree, in the Bighorn, Mid-Yellowstone, and Lower Yellowstone subbasins. In these five subbasins, salinity would increase enough that the water would be less desirable for such beneficial uses as irrigation and domestic water supply. In the upper Yellowstone, few problems would be expected.

In the Tongue and Powder rivers, any increase in water use will result in serious increases in salinity levels that are already high. In other subbasins, low-level and intermediate-level development would degrade water quality only enough to have minor effects on beneficial uses and the aquatic ecosystem.

Impact on Existing Municipal and Agricultural Users

If water use increases, the cost of providing water to cities in the basin will increase, but most of that increase would be due to increases in population and in the price of electricity. The effect of lowered water surface elevations would be insignificant.

There would likewise be some minor increases in pumping costs for irrigation pumping plants. The greatest impact to existing water users would be to those irrigators on the Yellowstone mainstem or affected tributaries whose gravity diversions have only a headgate and no diversion dam. Many of these diversions already have water accessibility problems during low-flow years. Any further reduction in flow would only increase those problems; it might become necessary to rechannel the river toward the diversions or to build diversion dams.

Swimming pool in Billings.

Impact on Fish and Wildlife

Aquatic invertebrates are highly sensitive to environmental change. Many of the changes associated with lowered streamflow, even if subtle, could reduce not only the numbers of invertebrates, but also the number of species of invertebrates. For instance, a reduction in flow would also reduce water velocity, and many invertebrate species prefer swift currents. If lowered flows expose portions of the river bottom, invertebrate habitat would be lost. A higher percentage of the stream bottom would be frozen in winter. Summer water temperatures would be higher. More silt would accumulate. Even if some of these changes are relatively minor, taken together, they would cause sufficient stress to kill large numbers of invertebrates, perhaps even the extinction of particular species.

A sound ecological principle is that everything affects everything else. The reduction in the aquatic invertebrates fed upon by fish would undoubtedly reduce the populations of game fish and "forage fish"—those fed upon by larger fish. But besides reducing the supply of food for fish species, the flow levels themselves would affect fish. In its investigation of the Tongue River fishery, for instance, the Yellowstone Impact Study discovered that even at intermediate-level development, streamflow would be insufficient for the spawning and rearing needs of channel catfish, sauger, and shovelnose sturgeon.

Just as a reduction in aquatic invertebrate populations would reduce the number of fish, so a reduction in fish populations would lower the number of fish-eating birds. Although some moderately important impacts, both positive and negative, would result from the lowering of the river's surface and from agricultural development along the river, waterfowl and other migratory birds would undergo extreme impacts from altered streamflow only if the form of the river's channel were changed—an impact that isn't expected. The same is true of the furbearing mammals that depend on the river, primarily beaver.

Impact on Recreation

The Yellowstone Impact Study determined that, although recreationists' access to the river might be improved by lowered flows during periods of what otherwise would have been high runoff, boating would be adversely affected. In fact, at many now-popular sites, little if any of the river's width would be navigable in August even at the low level of development. Fishing in the lower Yellowstone would deteriorate as well. Overall, recreation would be more adversely affected on the lower portion of the Yellowstone (below the mouth of the Powder River) than it would between Yellowstone Park and the Powder River.

Economic Impacts

Cost is defined by economists as any losses that people incur as a result of a proposed action, whether or not dollar values have been assigned to those losses. In that sense, all of the potential environmental impacts discussed on the previous pages—impacts on water quality, fish and wildlife, existing water users, recreation, and the river channel itself—should be considered the costs of increased withdrawals.

It can be demonstrated theoretically that there exists an economically best allocation of water between instream uses and withdrawals. Finding that allocation, by translating the theory into acre-feet of water, is difficult, but it is important to remember that it exists—in other words, that there is a particular level of withdrawals at which the costs of further withdrawals would exceed the economic benefits; when that point has been reached, it is neither environmentally nor economically desirable to appropriate any more of the river's flow.

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Kenneth A. Blackburn served as Yellowstone Impact Study project coordinator for the Old West Regional Commission.

The report was written by Shari Meats, Dave Lambert, Peggy Todd, Jim Bond, and Mark Nicholson. Overall editing responsibilities fell to Shari Meats and Dave Lambert. Proofreading and layout coordination were by William Phippen.

The "Projections of Future Development" and "Projections of Future Impact" sections of this report are summarized from the eleven technical reports produced for the Yellowstone Impact Study (inside front cover). Because the researchers and authors of those reports produced the information presented in this report, they are listed below by the section of this report in which their work was summarized.

What's Going to Happen?	Bob Anderson, DNRC Gary Fritz, DNRC Hanley Jenkins, DNRC Phil Threlkeld, DNRC
How Much Water Would Be Left in the River?	George Cawlfield, DNRC Satish Nayak, DNRC
Impact on the River Channel	Roy Koch, DNRC Peter R. Martin, Department of Fish, Wildlife, and Parks Robert Curry and Mark Weber, University of Montana, Geology Department
Impact on Water Quality	Jim Thomas, Duane A. Klarich, and Mona Jamison, Department of Health and Environmental Sciences
Impact on Existing Municipal and Agricultural Users	Mike Brown, DNRC Mel McBeath, DNRC
Impact on Fish and Wildlife	Robert L. Newell, Allen A. Elser, Robert C. McFarland, Dennis Schwehr, Tom Hinz, and Peter R. Martin, Department of Fish, Wildlife, and Parks
Impact on Recreation	Max L. Erickson, Department of Fish, Wildlife, and Parks
Economic Impact	Staff of DNRC's Water Resources Division

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APPENDIX

LAWS THAT REGULATE WATER USE IN THE YELLOWSTONE RIVER BASIN

Constitutional mandates, legal decisions, and laws—both federal and state—constrain the municipal, industrial, and agricultural use of water in the Yellowstone River Basin by requiring water uses to conform to agreed-upon goals and priorities established in the public interest through due process of law.

FEDERAL CONSTRAINTS

Perhaps the biggest contraint on water use in the Yellowstone River Basin is an unknown—namely, the scope of reserved water rights. Any discussion of reserved water rights necessarily begins with the U.S. Supreme Court's decision, *Winters v. United States* (1908). The Winters Doctrine, as extracted from the ruling and modified by subsequent decisions, states that federal or Indian land reserves withdrawn from the public domain (such as most federal forest land) hold a reserved right to the use of water within, crossing, abutting, or beneath the reservation. Whether or not exercised, the reserved right has continuous priority for an amount of water needed to serve the purposes for which the land reservation was established. Because the size of these reserved water rights is uncertain (they are potentially great), many states (including Montana) cannot gauge the amount of water remaining for allocation near federally-reserved land or Indian reservations.

Litigation in federal court to adjudicate federal and Indian reserved water rights under the Winters Doctrine in the Tongue and Bighorn river basins will take years. If the U.S. Government and the Crow and Cheyenne tribes are successful, the decision will affect many existing Montana water users regardless of the extent of their water rights under the law.

Other federal constraints on the use of water in Montana include the general environmental-preservation policy of the United States expressed in the National Environmental Policy Act and other acts regulating a variety of activities directly or indirectly affecting the use and diversion of water. These include constructing facilities for power generation, dams and diversions, and navigation facilities, or applying for permits for activities that affect water and air quality, the integrity of wilderness, the preservation of archaeological and historical sites, and endangered species. Of particular interest is the new federal power to regulate strip mining and subsequent land reclamation under the 1977 Surface Mining Control and Reclamation Act.

A federally-supervised agreement among the states of Montana, Wyoming, and North Dakota—the Yellowstone River Compact—regulates the division and diversion of water from the four major tributaries of the Yellowstone River between Wyoming and Montana, although some aspects of the pact are being challenged in court by private interests.

MONTANA CONSTRAINTS

The Montana Water Use Act of 1973 generally regulates the use of water in Montana and provides that its use for slurry of coal is not allowed. (The Yellowstone River Compact allows the states to authorize the diversion of water in one signatory state for use in another.) The Water Use Act also established a system for reserving water on behalf of federal and state agencies. The Montana Board of Natural Resources and Conservation has granted reservations in the Yellowstone River Basin. The allocation by the board could significantly constrain future water uses in the basin.

Other Montana laws affecting water use include the general environmental-preservation policy expressed in the Montana Environmental Policy Act, and acts regulating the construction and siting of major industrial facilities, controlling the development of flood plains and floodways, and regulating activities that could pollute and foul the air.

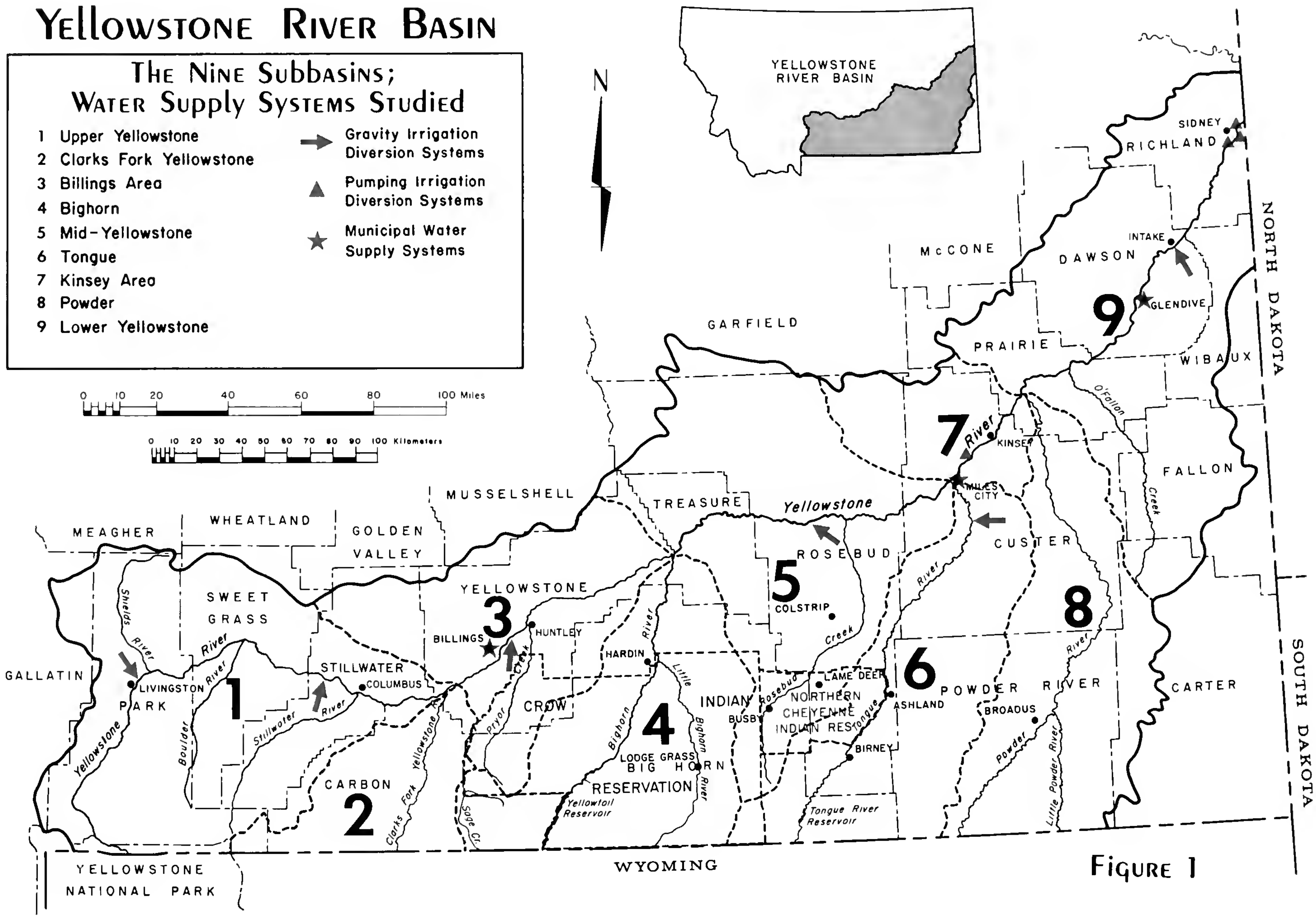
YELLOWSTONE RIVER BASIN
THE NINE SUBBASINS; WATER SUPPLY SYSTEMS STUDIED
1 Upper Yellowstone
2 Clarks Fork Yellowstone
3 Billings Area
4 Bighorn
5 Mid-Yellowstone
6 Tongue
7 Kinsey Area
8 Powder
9 Lower Yellowstone
Gravity Irrigation Diversion Systems
Pumping Irrigation Diversion Systems
Municipal Water Supply Systems
0 10 20 40 60 80 100 Miles
0 10 20 30 40 50 60 70 80 90 100 Kilometers
N
YELLOWSTONE RIVER BASIN
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
YELLOWSTONE NATIONAL PARK
GALLATIN
MEAGHER
WHEATLAND
GOLDEN VALLEY
MUSSELSHELL
GARFIELD
McCONE
RICHLAND
DAWSON
PRAIRIE
WIBAUX
FALLON
CARTER
CUSTER
POWDER RIVER
ROSEBUD
TREASURE
YELLOWSTONE
SWEET GRASS
PARK
STILLWATER
CARBON
BIG HORN
CROW INDIAN RESERVATION
NORTHERN CHEYENNE INDIAN RES
SIDNEY
INTAKE
GLENDIVE
KINSEY
MILES CITY
COLSTRIP
LAME DEER
ASHLAND
BIRNEY
BROADUS
BUSBY
LODGE GRASS
HARDIN
HUNTLEY
BILLINGS
COLUMBUS
LIVINGSTON
Yellowstone River
Shields River
Boulder River
Stillwater River
Clarks Fork Yellowstone
Pryor Creek
Sage Cr.
Bighorn River
Little Bighorn River
Yellowtail Reservoir
Rosebud Creek
Tongue River
Tongue River Reservoir
Powder River
Little Powder River
O'Fallon Creek
1
2
3
4
5
6
7
8
9

FIGURE 1

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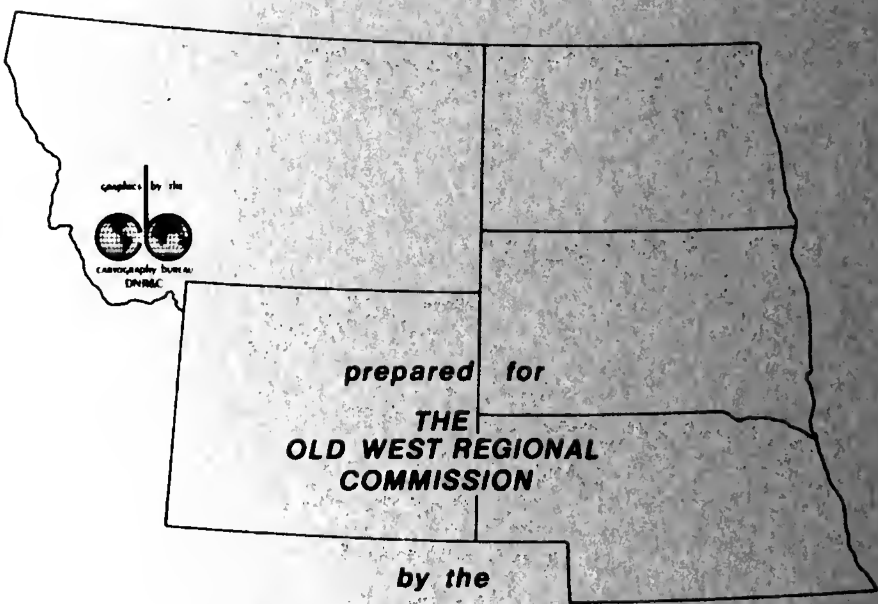

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